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SUPPLEMENT

TO THE

MANUAL

OF INSTRUCTIONS FOR THE

SURVEY OF DOMINION LANDS

DEPARTMENT OF THE INTERIOR

OTTAWA

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1917

Louis B. Stewart

DOMINION OF CANADA

SUPPLEMENT

TO THE

Manual of Instructions

FOR THE

Survey of Dominion Lands

DETERMINATION OF THE ASTRONOMICAL AND MAGNETIC MERIDIANS

PROBLEMS CONNECTED WITH THE SYSTEM OF SURVEY

TABLES

Issued by authority of the Honourable the Minister of the Interior

OTTAWA
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PREFACE.

The first Manual of Instructions for the survey of the Dominion Lands, a small 12mo pamphlet of thirty-two pages, was prepared in 1871 by Col. J. S. Dennis, Surveyor-General; the title was "Manual showing the System of Survey adopted for the Public Lands of Canada in Manitoba and the North-West Territories, with Instructions to Surveyors." It was published by authority of the Honourable the Secretary of State, the Dominion Lands office being then a branch of his department. The Manual contained only one table, "showing the departure in running 81 chains 50 links at any course from 1 to 60 minutes."

The second edition was prepared in 1881, under the direction of Mr. Lindsay Russell, Surveyor-General, by Dr. Deville; it was considerably enlarged, forming a large octavo book of 86 pages. By that time the need of tables specially adapted to the survey of Dominion Lands had become imperative: thirteen tables were calculated by Dr. Deville and Dr. King and were appended to that edition.

A number of editions followed, the fourth, published in 1892, containing six additional tables, or nineteen altogether. The fifth and sixth editions, issued in 1903 and 1905 respectively, contained only eight tables. The tables left out were seldom used and it was considered that when needed they could be consulted in the 1892 edition.

In 1908, when the stock of the fourth edition of the Manual (1892) was exhausted, a reprint of the tables became necessary. They were published as a supplement, and their construction and use fully explained. Problems connected with the system of survey originally published by Dr. King in the Report of the Department of the Interior for 1891, were appended.

For this edition, the Supplement has been completely revised. There have been added two chapters on observing and a chapter briefly describing the instruments kept in stock at the head office, for sale to surveyors employed by the Department. These chapters replace matter which formerly appeared in the Manual of Instructions. The additional chapters and the revision are the work of H. Parry, D.L.S.; he has carefully checked the tables and it is hoped that they will now be found free from errors.

INDEX TO THE NOTATION.

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a..... equatorial semi-diameter of the earth.
b..... polar semi-diameter of the earth.
c..... earth's compression.
e..... eccentricity.
h..... altitude of a star.
K..... distance.
L..... latitude.
l..... elevation above sea-level.
M..... longitude.
N..... length of normal to the meridian.
P..... radius of parallel of latitude; also polar distance.
p..... polar distance.
$R.A$..... right ascension.
R..... radius of curvature of meridian.
S..... radius of curvature.
t..... hour angle.
Z..... azimuth.

CHAPTER I.

THE DETERMINATION OF THE ASTRONOMICAL MERIDIAN.

The reference of lines to an astronomic meridian, in order to obtain their direction, or to check the accuracy of their production is most readily made by observations on the Pole star.

The telescopes used in the survey of Dominion lands, being amply powerful to show stars of the second magnitude within a few hours from noon, and stars of the third magnitude in twilight when it is still clear enough to read the graduations, the observations may be taken in daylight. Daylight observations have the advantage that they are conveniently made with the instrument at one of the stations for the ordinary production of the line, and during its progress, without materially interfering therewith; they enable the surveyor to avoid the inaccuracies and discomforts of working by artificial light.

STAR OBSERVATIONS IN DAYLIGHT.

In the western provinces and the Northwest Territories the air is in general exceedingly transparent, and with the telescopes now used most of the brighter stars can be seen at any time of the day; smaller stars are easier to observe when the sun is low. Observations on the Pole star may best be made about an hour before dusk, while there is still ample time for reading the verniers by daylight; it may also be observed in the morning.

To discover a star in the daytime requires a little patience and some practice, but once discovered it is easy to follow it or find it again. The telescope must be so directed as to bring the star within the field; how this is done is explained later. After clamping the telescope in the proper direction, the field is carefully scanned; it may be a minute or more before the star is perceived as a little speck of light in some corner of the field. A quick moving star is more easily found than one which moves slowly. The motion of the Pole star being almost imperceptible, a little movement to and fro given to the telescope by means

of the tangent screw of the vernier plate helps in perceiving it. Once found, it appears so plain that it is always a subject of surprise that it was not seen before.

It is essential that the telescope be very accurately focussed; if it is slightly out of focus the image of the star will be spread out and therefore very difficult to find. Instruments obtained from the department are first tested at the Surveys laboratory. There the tube of the telescope has a fine mark cut upon it indicating the position to which the objective must be racked out for solar focus. The objective tube must be accurately placed to this mark; this insures that the image of a star or distant object will fall in the plane of the diaphragm and that there will be no parallax. It remains now for the surveyor to focus the eyepiece accurately. This may best be done by placing the eyepiece approximately in focus on the diaphragm, sighting on a star not too bright—the Pole star for instance—and then screwing the eyepiece in or out until the star appears as a fine point. This position of the eyepiece should also show the cross hairs clear and distinct. For this position marks should be made with a sharp knife, one on the milled head of the eyepiece, and one on the collar or sleeve of the eyepiece tube, so that they are in line when the eyepiece is in focus. The surveyor can then at any time quickly adjust his instrument for astronomical observation, by racking out the objective tube to its mark, and by screwing the eyepiece in or out until the mark on the milled head is adjacent to the mark on the eyepiece sleeve. This position of the eyepiece will, of course, be different for different observers; it may vary slightly for the same observer according to the state of his eye, so that some slight adjustment may be necessary when first preparing for an observation.

OBSERVATION OF THE POLE STAR FOR AZIMUTH FOR SUBDIVISION PURPOSES.

Astronomical Field Tables are now supplied to surveyors in two sets, one giving data for star observations and the other giving data for sun observations. By means of the Star Tables the observation of the Pole star has become very easy and simple; the tables are not absolutely accurate, but they are good enough for subdivision purposes.

NOTE.—The Astronomical Field Tables may be obtained by applying to the Department.

For all astronomical work whether for time or azimuth the instrument must be very carefully levelled. In subdividing a township, an observation for azimuth is made on a section line or at a station of a traverse. The section line or the course of the traverse is taken as the reference line; in either case the bearing by account of the reference line is near enough to the azimuth for setting the instrument and finding the star. This may be done as follows:—

Set the vernier of the horizontal circle to read the approximate bearing of the reference line. Loosen the lower clamp and turn the instrument until the telescope is directed on the reference line; fasten the lower clamp, making the final pointing on the reference line with the lower plate tangent screw. Release the upper clamp. The instrument is now set to read bearings, which are near enough to azimuths for finding the star.

The two examples given on page 12 will now be explained.

Specimen Observations.—Explanatory Notes.

The following notes referring to the specimen observation on the upper half of page 12 show clearly how an observation should be taken and worked out.

The bearing of the reference line is known to be about 180° 05′. Set the vernier of the horizontal circle to read 180° 05′. Loosen the lower clamp and turn the instrument until the telescope is directed on the reference line. Fasten the lower clamp making the final pointing with the lower plate tangent screw. Release the upper clamp. The vernier now reads bearings or approximate azimuths.

The vernier is now set to read the azimuth of the star, which may be taken from the Astronomical Field Tables. In the example the Astronomical Field Tables show the azimuth of the Pole star for township 20 at sidereal time $16^h\ 30^m$ to be 1° 15′·2. The vernier is therefore set to read 1° 15′.

The telescope must now be set at the altitude of the Pole star. Take the latitude of the place from the diagram in the Field Tables. In the example, the latitude for township 27 is 51° 20′. Add or subtract the number of

POLE STAR OBSERVATION FOR AZIMUTH

Date Jan. 19, 8:45am 1916 Ref. line E by of Sec 18

Place N.E. cor. Sec 18 Tp. 27-20-3.

Face	H.C.R. on Ref. line	H.C.R. on Polaris	Watch Time
Right	180° 05′	1° 22′·5	16h 32m 57s
Left	0 04	181 22	16 35 07
Mean	180 04·5	1 22·2	16 34 02

Tab. az. for 16 h. 30 m. Tp. 20	1° 15′·2	Watch Corr.	− 48
Difference for 3 m. 14 s.	+ 1·0	Sid. Time	16 33 14
Difference for 6½ Tps.	+ 0·9		
Convergence for 2 Secs.	+ 2·2		
Bearing of Polaris	1 19·3		
H.C.R. on Polaris	1 22·2		
Correction to H.C.R.	− 2·9		
H.C.R. on Ref. line	180 04·5		
Bearing of Ref. line	180 01·6		

NOTE: If after observation any deflection in the line was made the following information should be supplied.

Amount — Direction —

Place

Date Mar. 1 5:10pm 1916 Ref. line N. by. Sec. 24

Place N.E. cor. Sec 24 Tp. 35-13-3

Face	H.C.R. on Ref. line	H.C.R. on Polaris	Watch Time
Right	269° 56′	358° 54′·5	3h 34m 35s
Left	89 56·5	178 52·5	3 37 29
Mean	269 56·2	358 53·5	3 36 02

Tab. az. for 3 h. 30 m. Tp. 20	359° 04′·7	Watch Corr.	+ 1 09
Difference for 7 m. 11 s.	− 3·0	Sid. Time	3 37 11
Difference for 15 Tps.	− 1·7		
Convergence for 3 Secs.	− 3·4		
Bearing of Polaris	358 56·6		
H.C.R. on Polaris	358 53·5		
Correction to H.C.R.	+ 3·1		
H.C.R. on Ref. line	269 56·2		
Bearing of Ref. line	269 59·3		

NOTE: If after observation any deflection in the line was made the following information should be supplied.

Amount — Direction —

Place

minutes in the first column of the "Table for finding the Pole star, etc." (Field Tables); the result is the altitude of the star. In the example, the number in the first column for sidereal time $16^h\ 30^m$ is 49′ to be subtracted, giving for the altitude 50° 31′. The telescope is set at this altitude.

With the telescope so set the star is in the field, and will be seen, provided the telescope is accurately focussed and the light not too strong. When found it is brought close to the middle horizontal thread. By means of the slow motion screw of the upper plate the vertical thread is brought over the star and the time by the watch noted at the instant the star is behind the thread. The horizontal circle vernier reading is then taken at leisure.

This is only one-half of the observation. For all azimuth work it is essential that the observation be made in two positions of the instrument, circle right and circle left. The position of the instrument is reversed by transiting the telescope and turning the vernier plate through 180°. The first part of the observation is now repeated. The horizontal circle reading on the reference line is recorded, the vernier set to read the azimuth of the star, the telescope set at the altitude and the field scanned for the star. When found, the star is again brought on the middle of the vertical thread and the time of the watch and the horizontal circle reading recorded.

'H.C.R. on Ref. line' is the vernier reading on the horizontal circle when the telescope is pointed on the reference line. 'H.C.R. on Polaris' is the vernier reading on the horizontal circle when the telescope is pointed on the Pole star. 'Watch Time' is the time by the sidereal watch at the instant the star is under the middle of the vertical thread of the diaphragm. These readings are taken, first *Face Right*, that is with the instrument set up so that the vertical circle is to the right of the telescope; and then *Face Left*, that is with the vertical circle to the left of the telescope. The vernier readings and the times are recorded in their proper spaces and the means taken.

The mean of the watch times must now be corrected for the error of the watch. The watch correction is obtained as shown in the examples of observations for time. In this observation the watch was 48^s fast and a correction of -48^s applied to the mean watch time $16^h34^m02^s$ gives $16^h33^m14^s$ as the mean sidereal time of the observation.

The next step in the computation is to find the bearing of the Pole star at sidereal time $16^h33^m14^s$ in the latitude of section 18, township 27 on the given date. The proper Field Tables for this observation are those for January, February and March, 1916, and April, May and June, 1917. From these tables the tabulated azimuth of the Pole star for sidereal time 16^h30^m and township 20 is $1° 15'·2$. To find the azimuth for sidereal time $16^h33^m14^s$ and section 18, township 27, corrections must be applied to $1° 15'·2$ for differences of 3^m14^s in time, and $6\frac{1}{2}$ townships in latitude. Thus the difference of azimuth taken from the tables for 10^m advance in the time is $+3'·2$; for 3^m14^s it is therefore $+1'·0$. The difference of azimuth taken from the tables for 20 townships advance in latitude is $+2'·9$; for $6\frac{1}{2}$ townships, it is therefore $+0'·9$. The convergence must now be applied to convert the azimuth to a bearing referred to the central meridian of the township. The place of observation is 2 sections west of the central meridian of the township, and the convergence taken from the diagram in the Astronomical Field Tables for township 27 is $1'·1$ per section. The sign of the convergence is + for points in the western half of the township. The convergence correction is therefore $+2'·2$.

The 'Bearing of Polaris' is found, by taking the algebraic sum of the four numbers above it, to be $1° 19'·3$.

The remainder of the reduction is self-evident. The mean 'H.C.R. on Polaris' is $1° 22'·2$. The 'Correction to H.C.R.' is the correction which must be applied to the horizontal circle readings to obtain bearings. It is the difference between the 'H.C.R. on Polaris' $1° 22'·2$, and the 'Bearing of Polaris' $1° 19'·3$, applied to the horizontal circle readings with the proper sign. In this observation, therefore, the 'Correction to H.C.R.' is $-2'·9$. This correction applied to the 'H.C.R. on Reference line' $180° 04'·5$, gives for the 'Bearing of Reference line' $180° 01'·6$.

The bearing found generally differs from the bearing by account which was 180°05′ in this example. The difference represents the accumulated errors of survey.

For the second specimen observation shown :—

The bearing of the reference line by account is 269° 56′. Hence the vernier is clamped to read 269° 56′, the lower clamp released and the telescope directed on the reference line. The lower plate is clamped in this position and the upper clamp released. The vernier now reads bearings or approximate azimuths.

The vernier is now set to read the azimuth of the star. From the Astronomical Field Tables, the azimuth of the star in township 20 at sidereal time $3^h\ 30^m$ is given as 359° 04′·7. The vernier is therefore set at 359° 05′.

The telescope is now set at the altitude of the star. The latitude of the place from the diagram in the Astronomical Field Tables is 52° 03′. For the altitude at sidereal time $3^h\ 30^m$, "Add to Latitude 59′" giving for the altitude 53° 02′. The telescope is set at this altitude.

As described in example No. 1 the star may now be found, brought under the middle of the vertical thread, and the time and horizontal circle reading noted. The face of the instrument is reversed, the horizontal circle reading on the reference object recorded, and the star found and observed.

The reduction of the observation is similar to the reduction of the observation explained above, and needs no further explanation.

It may be desired to observe at a place where no line of known bearing exists. For instance, the surveyor may wish while in camp to ascertain the time by the meridian transit of a star: for doing so, he has to set his instrument in the meridian by means of the Pole star. The method is the same as before, except that use is made of the compass for turning the instrument in the direction of the star. The compass box is set on the standard (not under the lower plate).

Having fixed the telescope at the proper altitude, as explained above, set the vernier of the horizontal plate to read the azimuth of magnetic north, taken from the small map showing "Azimuth of Magnetic North in Western Canada." These maps are printed on stiff cardboard of pocket size and are supplied to surveyors on request. Release the lower clamp and turn the instrument until the point of the needle is opposite the zero mark of its box. Fasten the lower clamp and release the upper one; the instrument is now set to read approximately azimuths. Set the vernier of the horizontal plate to read the azimuth of the Pole star taken from the table: if the magnetic declination and setting of the compass box were correct, the star should now be in the field of the telescope. The needle being subject to large variations, the star may be out of the field. If not found after looking carefully, the instrument is turned slowly, a degree or two on each

side, by means of the lower slow-motion screw. After finding the star, the vernier is again set to the azimuth from the Astronomical Field Tables for the time of the watch, and the star is brought under the vertical thread by means of the lower slow-motion screw. Now set the vernier at 360° and the telescope is in position for observing meridian transits of stars.

DETERMINATION OF THE ERROR OF THE WATCH.

In the observation for azimuth, the watch correction should be known within a minute. This correction has to be ascertained from time to time, more or less frequently according as the watch is of a better or an inferior grade.

The watch may first be set by means of the "sidereal time at noon, mountain time," given in the Astronomical Field Tables for the fifteenth of each month. For other dates, the time is calculated by interpolation, the variation being approximately four minutes a day. Mountain time is the time of the meridian of 105° west longitude: in that longitude, the watch is set to the sidereal time of the table when it is noon, mountain time. Further west, four minutes must be subtracted from the sidereal time at noon for every degree of longitude from the meridian of 105° west.

The watch having been set approximately to sidereal time, its correction is ascertained by observing the meridian transit of a star or of the sun.

DETERMINATION OF THE TIME BY THE MERIDIAN TRANSIT OF A STAR.

The observation of the meridian transit of a star is best made while surveying section or traverse lines, because the telescope is readily placed in the meridian by turning the requisite angle from a line of known bearing. At other places, the instrument is placed in position by means of the compass and the Pole star, as previously explained.

After placing the instrument in the meridian, the telescope is set at the altitude of the star, which is obtained by subtracting the polar distance from the supplement of the latitude. The stars in the Astronomical

Field Tables pass the meridian south of the zenith. The telescope being in position, the field is examined for the star a little before the time of transit. With the long diagonal eyepiece, the star enters the field on the left; with the inverting eyepiece, it enters on the right. The star moves through the field and when it crosses the vertical thread the time of the watch is noted.

The examples and explanations appended show how the watch correction is deduced.

In example No. 3 it is desired to observe for time by the meridian transit of a star, the approximate sidereal time being 14^h. By consulting the list of time stars given in the Astronomical Field Tables, it is found that Arcturus is a convenient star transiting at $14^h\ 11^m$. The latitude of the observation place from the Astronomical Field Tables is 59° 57′ and its supplement 120° 03′; subtracting the polar distance of Arcturus 70° 23′, gives for the altitude 49° 40′, at which the telescope is set.

In example No. 4 the approximate sidereal time is 4^h and the next convenient time star is found to be Aldebaran which transits at $4^h\ 31^m$. The latitude of the place is 54° 15′ and its supplement 125° 45′; subtracting the polar distance of Aldebaran 73° 39′, gives for the altitude 52° 06′. The calculation for the altitude is made roughly; a few minutes more or less does not matter.

Example No. 3.—Time by Meridian Transit of a Star.

DATE—Oct. 2, 1915. 1.30 p.m., local mean time.
PLACE—Sec. 12, tp. 126–1–6.

(1)	Watch time of meridian transit of Arcturus	$14^h\ 10^m\ 32^s$
(2)	Sidereal " " "	$14^h\ 11^m\ 49^s$
(3)	Watch correction (watch slow)	$+1^m\ 17^s$

Example No. 4.—Time by Meridian Transit of a Star.

DATE—Aug. 12, 1915. 7 a.m., mountain time.
PLACE—Sec. 33, tp. 60–19–3.

(1)	Watch time of meridian transit of Aldebaran	$4^h\ 32^m\ 03^s$
(2)	Sidereal " " "	$4^h\ 31^m\ 05^s$
(3)	Watch correction (watch fast)	-58^s

(1) This is the time shown by the watch when the star crosses the vertical thread of the diaphragm, the telescope having previously been set in the meridian.

(2) The sidereal time of meridian transit is taken from the table of time stars given in the Astronomical Field Tables.

(3) The watch correction is + when the watch is slow and − when the watch is fast.

DETERMINATION OF THE TIME BY THE MERIDIAN TRANSIT OF THE SUN.

The determination of the watch correction by means of the meridian transit of the sun is a very convenient method. The observation is made at a time of the day when the instrument is on the survey and therefore can readily be set in the meridian, there is no difficulty in finding the sun, and moreover it can be observed through light clouds or haze when stars are invisible.

The observation is exceedingly simple. The telescope is set in the meridian as explained for a star transit, and a note is made of the times shown by the watch when the first limb and the second limb cross the vertical thread of the diaphragm. The observation is, of course, made with the coloured glass. The Apparent Right Ascension of the sun at the time of observation must now be calculated; it is found by adding the variation for the longitude to the Right Ascension at Greenwich Apparent Noon given in the Astronomical Field Tables.

The longitude of the place of observation, which is required for calculating the variation of the Right Ascension, is taken from the diagram in the Astronomical Field Tables where it is given in hours and tenths. The variation in one hour is given in the table in the column next to the Right Ascension: the variation for the longitude is the product of the longitude expressed in hours and decimals by the variation in one hour.

The details of the calculation are shown in examples Nos. 5 and 6 and in the notes appended.

Example No. 5.—Time by Meridian Transit of the Sun.

DATE—April 17, 1915.
PLACE—Sec. 36, tp. 91–1–6.

(1) Transit of first limb	$1^h\ 34^m\ 23^s$
(2) Transit of second limb	$1^h\ 36^m\ 33^s$
Mean	$1^h\ 35^m\ 28^s$
(3) Sun's R.A. at Gr. App. Noon	$1^h\ 37^m\ 56^s$
(4) Var. in $7^h{\cdot}87 = 7{\cdot}87 \times 9^s{\cdot}3$	$+\ 1^m\ 13^s$
(5) Sun's R.A. at observation	$1^h\ 39^m\ 09^s$
(6) Watch correction (watch slow)	$+\ 3^m\ 41^s$

Example No. 6.—Time by Meridian Transit of the Sun.

DATE—August 27, 1915.
PLACE—Sec. 1, tp. 29–9–E.

(1) Transit of first limb	$10^h\ 21^m\ 09^s$
(2) Transit of second limb	$10^h\ 23^m\ 18^s$
Mean	$10^h\ 22^m\ 13^s{\cdot}5$
(3) Sun's R.A. at Gr. App. Noon	$10^h\ 20^m\ 16^s$
(4) Var. in $6^h{\cdot}4 = 6{\cdot}4 \times 9^s{\cdot}2$	$+\ 59^s$
(5) Sun's R.A. at observation	$10^h\ 21^m\ 15^s$
(6) Watch correction (watch fast)	-58^s

(1) This is the time shown by the watch when the first limb of the sun crosses the vertical thread of the diaphragm, the telescope having been previously set in the meridian.

(2) This is the time by the watch at the crossing of the other limb.

(3) The Apparent Right Ascension of the Sun at Greenwich Apparent Noon is taken from the Astronomical Field Tables.

(4) The longitudes of $7^h{\cdot}87$ in example No. 5 and $6^h{\cdot}4$ in example No. 6 are obtained from the diagram in the Astronomical Field Tables. The variation in one hour of the Sun's Right Ascension, $9^s{\cdot}3$ in example No. 5 and $9^s{\cdot}2$ in example No. 6, is given in the table of the Sun's Apparent Right Ascension.

(5) The Sun's Right Ascension at the time of observation is the sum of the Right Ascension at Greenwich noon and the variation in $7^h \cdot 87$ or $6^h \cdot 4$, the longitude of the place of observation.

(6) The watch correction is obtained by subtracting the watch time from the Sun's Right Ascension at observation.

OBSERVATION OF THE SUN FOR AZIMUTH FOR SUBDIVISION PURPOSES.

Star observations require a clear sky; they may be prevented by smoke, haze or light clouds, while the sun is quite visible. It may therefore happen that the observation of the sun will be the only method available for the determination of the azimuth.

The method is not as accurate as with Polaris and as it involves considerable calculation it is more liable to errors. It is not recommended when Polaris can be observed.

The instrument must be provided with a dark coloured glass for observing the sun through the telescope.

The observation is made first with the vertical circle in one position, to the right of the observer for instance, and next with the circle to the left, after reversing the telescope and turning the upper plate 180°.

The explanations which follow are based on the use of the inverting eyepiece.

The observations are easy enough if made methodically, otherwise there is a risk of not placing the images in opposite angles of the threads of the diaphragm, which would entirely vitiate the result. The rules given, if learned by heart so as to be carried out without any hesitation, will prevent mistakes.

In the first position of the instrument, the image of the sun is brought into the angle formed by two of the threads in the telescope so as to be tangent to both at the same time. The same process is repeated with the instrument in the second position, but with the sun's image in the opposite angle (figs. 1 and 2).

In order to bring both threads tangent to the sun's limb at the same time, the sun's image must be so placed as to move towards one thread while going away from the other. The former thread is kept tangent to the limb by the proper slow motion screw until both threads are tangent together. In the opposite angle of the threads the same process is repeated with the other slow motion screw.

Fig. 1 shows how the sun's image appears to move in the forenoon with an inverting eyepiece. In the upper left angle of the threads the sun's image moves away from the vertical thread and towards the horizontal thread; the latter is kept tangent by the slow-motion screw of the vertical circle. In the lower right angle of the threads, the sun's image moves away from the horizontal thread and towards the vertical thread, the latter being kept tangent by the slow-motion screw of the horizontal circle. Fig. 2 shows how the discs would be placed in the afternoon.

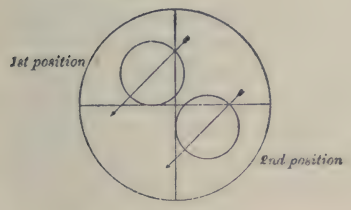


FIG. 1.

Observation of the sun in the forenoon with an inverting eyepiece.

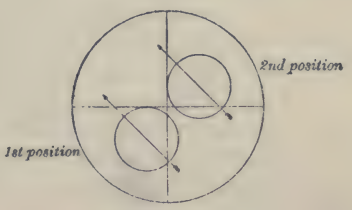


FIG. 2.

Observation of the sun in the afternoon with an inverting eyepiece.

Rules for Observing.—1. Commence with the sun on the left of the vertical thread and impinging upon it, above the horizontal thread in the forenoon and below in the afternoon.

2. Follow the sun with the slow motion screw of the vertical circle until the vertical thread also becomes tangent to the disc.

The rules are reversed in the second position of the instrument.

3. Place the sun on the right of the vertical thread and impinging upon the horizontal thread, below it in the forenoon and above it in the afternoon.

4. Follow the sun with the slow-motion screw of the upper plate until the horizontal thread also becomes tangent to the disc.

The readings of the vertical circle on the sun, and of the horizontal circle on both the sun and the reference object, generally one of the line pickets, must be taken in both positions of the instrument and the approximate time of the observation noted.

The following formula may be used for the calculation:

$$\cos\frac{a}{2} = \sqrt{\cos S \cos (S-P) \sec L \sec h}$$

$$\text{where } S = \frac{h + L + P}{2}$$

h = sun's true altitude,
P = sun's polar distance,
L = latitude of observation station,
a = angle sun makes with the meridian east or west from the north.

Then the azimuth from the north through the east, south and west is the same as "a" for forenoon observations, and is "360–a" for afternoon observations.

The latitude and the logarithm of its secant are given in Table X for the north side of every section.

The mean refraction and sun's parallax, as well as the sun's apparent declination, are given in the Solar Astronomical Field Tables.

COMPUTATION FOR SUN OBSERVATION.

Sample observations and computations are given on pages 23 and 24.

As has been stated above, the reduction of a sun observation for azimuth involves considerably more calculation than the reduction of an observation on the Pole star. The observation form and the reduction of the observation are briefly explained below.

The instrument is first carefully set up at the station and levelled. In observing it is a good practice to form the habit of always beginning the observation with the instrument in the same position, say the 'Face Right' position. The reference line is sighted on and the horizontal circle reading recorded. The sun glass must then be attached to the eyepiece, the instrument pointed at the sun and the telescope directed by the vertical circle screw and the upper horizontal plate screw so that the vertical and horizontal webs of the diaphragm are both tangent to the sun's disc. The rules for observing given on page 21 should be closely followed. The vertical circle reading is then taken and recorded under 'Sun's Altitude' and the horizontal circle

SUN OBSERVATION FOR AZIMUTH

Date Oct. 16 1915 Ref. line E by. Sec 5

Place 25 chs. S. of N.E. cor. Sec. 5. Mp. 28-23-3

Face	Watch	H.C.R. on Ref. line	Sun's Altitude	H.C.R. on Sun
R	h m 8 10 am	0° 01'	12° 30'	120° 51'
L	8 12	180 01	12 11	301 39
Mean	8 11	0 01	12 20·5	121 15

Obs. Alt. Sun's Cent.	12° 20' 5	Sun's Dec. G.M.N.	S 8° 35' 4
Refraction −	3·9	Var. for 3·2 hrs.	+ 3·0
Parallax +		Dec. at 8 − 11 a.m.	S 8 38·4
Sun's True Alt. (h)	12 16·6	Sun's Pol. Dist. (P)	98 38·4
Stan. Mtn. ~~Local~~ Time	h 8·2 a.m.	$\cos\frac{a}{2}$ = cos S cos (S−P) sec L sec h	
Longitude	7	P = Polar Dist., h = True Alt. Sun's Centre	
Greenwich M. Time	3·2 p.m.	L = Latitude, S = ½(P + L + h)	

h = 12° 16' 6	log sec h =	0·01005	log cos h = T·98995
L = 51 22·1	log sec L =	0·20460	log sec h = 0·01005
P = 98 38·4	log cos S =	T·18741	
2S = 162 17·1	log cos (S−P) =	T·97943	log cos L = T·79540
S = 81 08·6	log $\cos^2\frac{a}{2}$ =	T·38149	log sec L = 0·20460
S−P = 17 29·8	log $\cos\frac{a}{2}$ =	T·69075	
	$\frac{a}{2}$ =	60° 37' 1	
	a =	121 14·2	

NOTE: If after observation any deflection in the line was made the following information should be supplied.

Azimuth of Sun	= 121 14·2	Amount — Direction —
Convergence for 1 Sections	= + 1·1	Place
Bearing ref. to Cent. Mer.	= 121 15·3	
H.C.R. on Sun	= 121 15	
Correction to H.C.R. on Sun	= + 0·3	
H.C.R. on Reference Line	= 0 01	Bar. 27·9 ins.
Bearing of Reference Line	= 0 01·3	Temp. 50° F.

SUN OBSERVATION FOR AZIMUTH

Date July 1st 1913 Ref. line N by Dec 26.
Place 25 chs W of N.E. cor. Dec 26 - Mn 24-13-6.

Face	Watch	H.C.R. on Ref. line	Sun's Altitude	H.C.R. on Sun
R	h m 5 15 p.m.	270° 00'	24° 55'	276° 30'
L	5 17	90 00	25 11	96 15
Mean	5 16	270 00	25 03	276 22·5

Obs. Alt. Sun's Cent.	25° 03'	Sun's Dec. G.M.N.	N 23° 08'·8
Refraction −	− 1·7	Var. for 13·3 hrs.	− 2·2
Parallax +		Dec. at 5-16 p.m.	N 23 06·6
Sun's True Alt. (h)	25 01·3	Sun's Pol. Dist. (P)	66 53·4

Local Time	5h 3 p.m.	$\cos\frac{q}{2} = \cos S \cos(S-P) \sec L \sec h$
Longitude	8·0	P=Polar Dist., h=True Alt. Sun's Centre
Greenwich M. Time	13·3 p.m.	L=Latitude, $S = \frac{1}{2}(P + L + h)$

h = 25° 01'·3	log sec h =	0·04280	log cos h = T·95720
L = 51 04·9	log sec L =	0·20189	log sec h = 0·04280
P = 66 53·4	log cos S =	T·50155	
2S = 142 59·6	log cos(S−P) =	T·99860	log cos L = T·79811
S = 71 29·8	log $\cos^2\frac{q}{2}$ =	T·74484	log sec L = 0·20189
S−P = 4 36·4	log $\cos\frac{q}{2}$ =	T·87242	
	$\frac{q}{2}$ =	41° 48' 1	
	a =	83 36·2	

NOTE: If after observation any deflection in the line was made the following information should be supplied.

Azimuth of Sun	= 276 23·8	Amount = Direction =
Convergence for 7 Sections	= − 1·8	Place
Bearing ref. to Cent. Mer.	= 276 22·0	
H.C.R. on Sun	= 276 22·5	
Correction to H.C.R. on Sun	= − 0·5	
H.C.R. on Reference Line	= 270 00	Bar. 28·5 ins.
Bearing of Reference Line	= 269 59·5	Temp. 60° F.

reading taken and recorded under 'H.C.R. on Sun'. The approximate local mean time is required in the reduction of the observation; it is sufficient to note it on an ordinary mean time watch before reading the verniers.

The face of the instrument is now reversed and the above process repeated for the 'Face Left' position of the instrument, carefully following the rules laid down on page 21 as to the angle of the diaphragm in which the sun's image must be placed.

In the reduction of the observation the means of the time, H.C.R. on Reference line, Sun's Altitude and H.C.R. on Sun are first calculated.

The sun's true altitude to be used in the reduction, is the mean of the observed altitudes corrected for refraction and parallax. A table of the combined mean refraction and parallax is given in the Astronomical Field Tables for solar observations. The table also gives the corrections which should be applied thereto for temperature and pressure, in order to find the mean refraction and parallax for the atmospheric conditions at the time of observation. In the observation on page 23, the mean of the observed altitudes is $12° 20'·5$. The combined refraction and parallax for this altitude is given as $4'·2$. For a barometric pressure of $27·9$ inches a correction of $-0'·3$ must be applied. For a temperature of 50°F. no correction is required. Hence the resultant correction for refraction and parallax is $3'·9$; this correction is always to be subtracted from the observed altitude. The sun's true altitude therefore in the example is $12° 16'·6$.

The next step in the reduction of the observation is to find the sun's polar distance. The Astronomical Field Tables for solar observations give the sun's apparent declination at Greenwich mean noon and the variation for one hour. We must therefore know the time after Greenwich mean noon at which the observation was taken. This is obtained by adding the local mean time to the longitude expressed in time. Thus in the example on page 23 the observation was taken at 8^h11^m a.m. standard mountain time,* which is the local time for longitude 105° west, and is 7^h behind Greenwich mean time. The Greenwich mean

*When local time is used, as was the case in the observation shown on page 24, the approximate longitude of the place is required. This may be taken, expressed in hours and tenths, from the diagram in the Field Tables for Pole star observations.

time of the observation is therefore $8^h \cdot 2$ a.m. $+ 7^h = 3^h \cdot 2$ p.m., that is, the observation was taken $3^h \cdot 2$ after mean noon at Greenwich on October 16th. From the table, the sun's declination at mean noon on October 16th, 1915 was S. $8° 35' \cdot 4$ and the variation for one hour $0' \cdot 93$. For $3^h \cdot 2$ the variation is therefore $3' \cdot 0$ and the declination South $8° 38' \cdot 4$, that is, a polar distance of $98° 38' \cdot 4$.

The latitude of the observation station is given in Table IX or Table X.

The form shows a convenient method of working out the formula and the reduction of the observation then proceeds similarly to the reduction of the observation on the Pole star, and needs no further explanation.

The best time for observing is when the sun is on the prime vertical, as an error in the altitude has then the least effect upon the azimuth. The surveyor should, therefore, endeavour to observe at about that time whenever possible. Useful observations, however, may be made at other times within certain limits. These limits are entirely arbitrary, but are based upon practical considerations.

For the lower limit in altitude there has been taken the value of eight degrees, as it is considered that for an altitude lower than this the refraction correction is too uncertain in value.

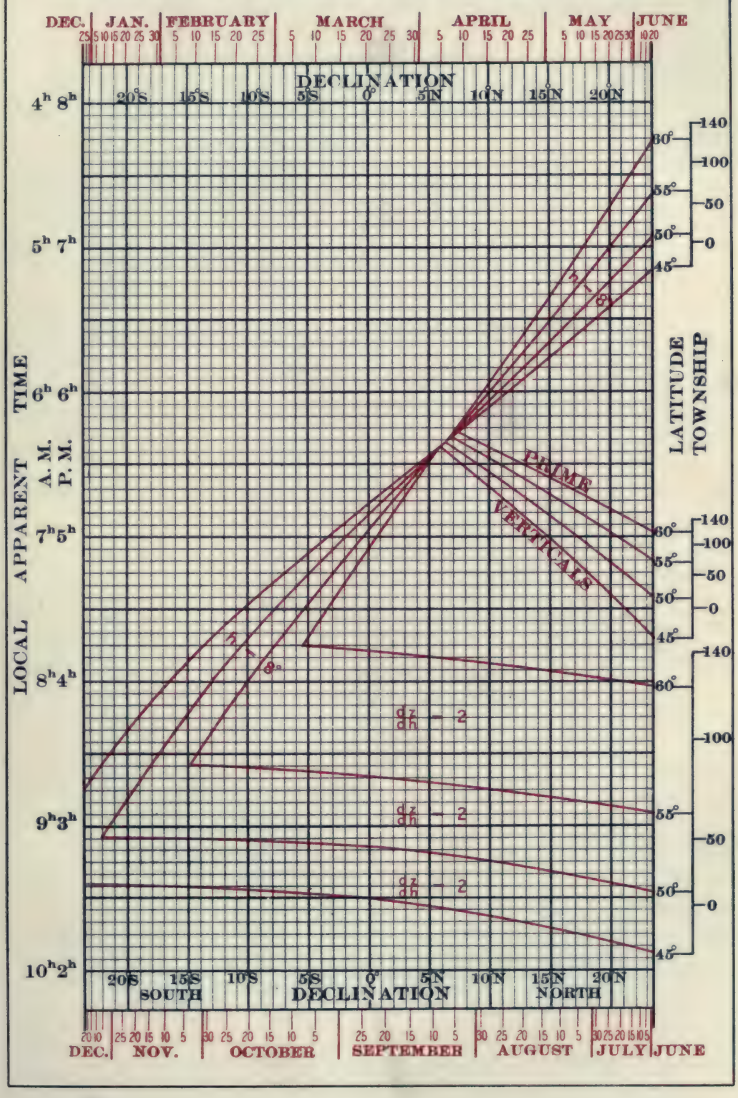
For the upper limit in altitude there has been taken that altitude where the rate of change of azimuth is double the rate of change of altitude, as for altitudes higher than this an error in altitude would produce too large an error in azimuth.

To any observer, therefore, who wishes to obtain results to which he may attach a reasonable weight, and also to any observer who wishes to know definitely that he is working under conditions such as will guarantee a value returned commensurate with the energy expended, the above limits will commend themselves, for outside of these limits an observation for azimuth possesses but small value, even when made by a skilled observer.

Instead of expressing these limits in terms of the altitude, the equivalent local apparent times have been calculated and plotted in the diagram of Plate I.

Therefore, by consulting this diagram, the surveyor knowing the date and latitude, is able to see at a glance the apparent times in the forenoon and afternoon when

DIAGRAM INDICATING FOR EACH DAY OF THE YEAR THE BEST TIME AND THE LIMITS OF TIME FOR SOLAR ALTITUDE-AZIMUTH OBSERVATIONS.



the sun is on the prime vertical, and the apparent times in the forenoon and afternoon between which he will have to observe in order to keep within the two above limits.

For example: A surveyor in township 70, range 17, west of the Fifth meridian wishes to know for May 15th, 1917, the best local apparent times in the forenoon and afternoon for making an altitude-azimuth observation, and also the limits of time.

The date, May 15th, is found at the top of the diagram. Projecting this point vertically downwards to the "prime vertical" curve representing township 70 (approximately 55° N. latitude) and then horizontally to the left to the scale of time, there are obtained the local apparent times $6^h\ 56^m$ a.m. and $5^h\ 04^m$ p.m. when the sun is on the prime vertical.

Similarly from the "$h = 8°$" curve representing township 70 there are obtained the local apparent times $5^h\ 08^m$ a.m. and $6^h\ 52^m$ p.m. when the altitude is 8°; and from the "$\frac{dZ}{dh} = 2$" curve representing township 70 there are obtained the local apparent times $8^h\ 51^m$ a.m. and $3^h\ 09^m$ p.m. when the altitude is such that "$\frac{dZ}{dh} = 2$." Therefore, in the forenoon altitude-azimuths may be observed from $5^h\ 08^m$ to $8^h\ 51^m$, the best time for observing being $6^h\ 56^m$.

And in the afternoon altitude-azimuths may be observed from $3^h\ 09^m$ to $6^h\ 52^m$, the best time for observing being $5^h\ 04^m$.

Similar information for every date and declination, and every township and latitude is given by this diagram.

According to the diagram, the sun may be observed on the prime vertical from about April 7th to about September 7th, or five months in the year.

Since only the approximate times are required, the diagram may be used for all years.

It will be noted that for some latitudes the curves of "$h = 8°$" and "$\frac{dZ}{dh} = 2$" intersect. Therefore, for dates to the left of these points of intersection there do not occur any periods of time during which altitude-azimuths may be observed between the assumed limits. Thus for latitude 55° N. observations may not be made between the dates of November 3rd and February 9th.

OBSERVATION OF POLARIS FOR AZIMUTH ON GOVERNING SURVEYS.

On the governing surveys of the Dominion lands system where great precision is required, the observation for azimuth is made with a six-inch transit theodolite as described on page 52, and the degree of accuracy aimed at makes the observation somewhat more complex in all its details than the method described for subdivision surveys. Some of the special precautions and refinements necessary are mentioned below.

For accurate work a good solid set-up for the instrument is essential.

As in all angular measurements, care should be taken when turning the instrument in azimuth by hand, to use the same forward or backward motion throughout for every pair of pointings, the angle between which is intended to be read on the horizontal circle. This tends to obviate the effect of any yield in the instrument stand to that part of the impulse of revolution that passes down through the foot screws to the stand head. A source of similar error is looseness of foot screws in their nuts. The pinch screws closing these last should always be screwed up before finally adjusting the levelling screws, so as to have them turning stiffly in their nuts. Even though this may be less convenient to the observer in bringing quickly, and with nicety, his level bubbles to their desired position, the certainty that it ensures warrants it.

The tangent and micrometer screws should always be turned so as to push against the counteracting spring; because in turning in the opposite direction, the spring might fail to bring back the plate at once and do so only during the interval between the observation and the reading of the drum.

The reference object for azimuth work should be, if possible, at such a distance that the telescope is at solar focus when the pointing is made on the reference object.

In observing for azimuth the following programme may generally be adopted:

1. Level the instrument very carefully using the striding level for this purpose, so that the level correction may be small.

2. Point on the reference object and read the microscopes three times each on forward and backward graduations.
3. Point approximately on Polaris and place the striding level in position (zero of graduation to the right or east). Point accurately on Polaris noting the time by sidereal watch. Read the striding level, reverse it, and read it again. Read the microscopes three times each on forward and backward graduations.
4. Reverse the telescope in altitude, turn the instrument 180° in azimuth, and repeat as in No. 3. The striding level must, of course, be removed while the telescope is being transited.
5. Same as No. 2.

A complete observation as above should, under favourable conditions, give a result correct to within a few seconds. It may be remarked however that observations in the field are seldom taken under ideal conditions and it is strongly to be recommended that two or more observations be taken at a station whenever weather conditions will allow. This course should always be adopted when the bearing of the line is much in doubt; the range of the results then provides some criterion of the accuracy of observing.

In the special case where the reference object is on or near the meridian, the observation for azimuth can be arranged so as to be independent of the readings of the graduation, which need not be taken, the difference in azimuth between the star and the reference object being measured by means of the eyepiece micrometer.

The programme is as follows:—

1. Level the instrument very carefully using the striding level for this purpose, so that the level correction may be small.
2. Point approximately on Polaris and place striding level in position (zero graduation to the right or east).

   Bisect the star with the movable thread, noting the time by sidereal watch. Read the striding level and reverse it. Bisect the star again with the movable thread, noting the watch time. Read the striding level and remove it.
3. Lower the telescope and bisect the reference object twice with the movable thread.

4. Set the movable thread in the symmetrical position on the opposite side of the middle thread, reverse the telescope and turn the instrument around in azimuth until the movable thread is on the reference object. Fasten the clamping screw, and bisect the reference object twice with the movable thread.
5. Same as No. 2.

Under favourable conditions, the result by this method should be accurate within three or four seconds. It is important that the telescope be set to solar focus very accurately. An error of one thousandth part of the focal length in the adjustment causes a corresponding error in any angle measured with the eyepiece micrometer. If the angle is, for instance, fifty minutes, the error is one-thousandth part of fifty minutes or three seconds. It is therefore advisable to use a magnifying glass in extending the telescope to the focal mark.

Whichever programme be adopted it will be found convenient in order to prevent mistakes always to begin the observation with the same position of the instrument.

The error of the watch is required for the reduction of the observations. In observing Polaris near upper or lower transit an error of one second of time corresponds in the latitude of the western provinces to an error in azimuth of half a second of arc more or less. The error of the watch should therefore be known with some precision. An observation for time should be taken either shortly before or shortly after every azimuth observation. The instrument should be carefully levelled with the striding level and the observed transit corrected for level and azimuth errors according to the methods prescribed in any of the standard text books on astronomy.

If Polaris is sufficiently close to the meridian, a convenient way of setting the instrument in the meridian is by the eyepiece micrometer. Set the azimuth of Polaris off from the collimation (correcting for altitude by dividing by the secant of the altitude) with the movable wire and by turning the tangent screw bisect the star with the movable wire. Observe the times of transit of some time star across the fixed wires.

The result of the observations for time must always be entered in the form at the beginning of the book of record of astronomical observations.

The striding level is graduated from zero at one end, continuously upwards to the other end. Representing by w and e the readings of the west or left and east or right extremities of the bubble respectively when the zero of the graduation is at the east or right end and by w' and e', the corresponding west and east readings after the level is reversed, that is to say, when the zero of the graduation is at the west or left end, d being the value of one division in seconds of arc, the level correction is:

$$\frac{d}{4}\left\{(w-w') + (e-e')\right\} \tan h$$

Tan h, the inclination factor for Polaris, is tabulated in the azimuth observation book.

If the observation is taken according to the first programme, the level correction is applied to the horizontal circle readings according to sign; but if taken by the micrometric method the level correction is applied to the angle "Polaris from collimation" according to sign if Polaris is east of collimation, opposite to sign if west.

The determination of the value of one division of the level is ordinarily made at the Surveys laboratory. If however, the surveyor has no knowledge of his level value and wishes to determine it in the field, he may adopt the following method:—

The level is placed on the upper plate parallel to the plane of revolution of the telescope, and a mark set up at a distance such that the telescope may be in solar focus and in the direction of one of the foot screws. The bubble is, by turning this foot screw, brought close to one end of its run, the telescope is pointed on the mark and firmly clamped. A careful pointing is now made on the mark with the movable thread of the eyepiece micrometer and the readings of the micrometer and level noted. The foot screw is then turned until the bubble is close to the other end of its run, the drum of the eyepiece micrometer turned until the movable thread again bisects the mark and the micrometer and level readings noted. The difference of micrometer readings gives the angular displacement from which the value of one division of the level may be derived. The operation should be repeated several times. The level may be reversed end for end during the course of the determination if desired.

Instead of a distant point, the pointings may be made upon the telescope of a transit or level used as a collimator.

In the reduction of an observation taken according to the second programme, "circle east" and "circle west" are reduced independently, the mean of the micrometer readings on the reference object and star and of the watch times being taken in each case. The correction for curvature of the path of Polaris, being in extreme cases only a fraction of a second, may be neglected.

The angle measured by the micrometer between the star and the line of collimation and, when the reference object has any appreciable altitude, between the reference object and the line of collimation, must be multiplied by the secant of the altitude to reduce it to the horizontal. When Polaris is sufficiently close to the meridian to allow it, it will be better to make the pointing with the movable thread on Polaris not far from the centre of the field. In this way the factor for the reduction to the horizontal of the angle "Polaris from collimation" affects only a small angle while the factor for the reduction of the large angle "Reference object from collimation" is nearly unity. The altitude of Polaris may be taken from the Astronomical Field Tables for the mean of the times of the two observations, "circle right" and "circle left," without appreciable error. At or near elongation when the altitude is changing rapidly and when the angle "Polaris from collimation" is necessarily large, the altitude is better read off the vertical circle, each half of the observation being reduced with its own altitude.

To reduce the micrometer readings to arc, the value of one turn is required. This is ordinarily determined at the Surveys laboratory. But if the surveyor is without this value, he may find it by any of the methods described in standard text books on astronomy.

The following method will be found convenient:—

Set the movable wire of the micrometer close to one end of its run and move the upper part of the instrument with the tangent screw until the movable wire bisects some distant object (solar focus) at the same level as the transit; read the micrometer once and the horizontal circle microscopes three times. Now bring the movable wire close to the other end of its run and bisect again the same point with the movable wire by means of the tangent screw, reading the micrometer and circle microscopes as before.

The horizontal angle as shown by the microscope readings divided by the difference of micrometer turns gives the value of one turn of the micrometer.

The operation should be repeated a number of times and, in order to eliminate as much as possible periodic errors of the circle graduation, the instrument should be revolved by means of the shifting head on the stand to give readings on different parts of the circle.

The uniformity of the micrometer screw may be tested by measuring the value of one turn over different parts of the screw.

Another transit or a level may be used as a collimator and gives a better reference object than a distant point. Set up the collimator a few feet from the transit to be tested and with the telescope at the same level. Adjust both to solar focus and point on the object glass of the transit. Now looking at the collimator through the telescope of the transit, the cross wires or points of the collimator telescope will be seen as at an infinite distance. These cross wires or points make an excellent reference object.

Surveyors are at liberty to use any formula or process for reducing their observations, but, as forms and tables could not be prepared for every method, the following formula has been adopted; for convenience, with regard to future reference, it is desirable that all surveyors should adopt it:—

$$*\tan Z = -\frac{\tan P \sec L \sin t}{1-\tan P \tan L \cos t}$$

where Z, P, L, t, are azimuth, polar distance, latitude and hour angle respectively.

Writing m for $\tan P \tan L \cos t$ the formula may be written

$$\tan Z = -\left(\frac{1}{1-m}\right) \tan P \sec L \sin t$$

---

*The formula may be deduced as follows:—

In the spherical triangle defined by the star, the zenith and the pole, the hour angle t is measured from upper culmination, and the azimuth Z is positive or negative according as the star is east or west of the meridian.

Table XIII gives the values of $\log \frac{1}{1-m}$ tabulated with $\log m$ as argument; in using these tables attention must be paid to the sign of m which is the same as that of $\cos t$. When t lies between 0^h and 6^h, or 18^h and 24^h, m is positive and the half of the table as given on pages 146, 148 and 150 must be used; when t lies between 6^h and 18^h, m is negative and the half of the table as given on pages 147, 149 and 151 must be used.

Since m is always less than unity, $\frac{1}{1-m}$ is always positive, and therefore $\tan Z$ is of opposite sign to $\tan P \sec L \sin t$. Hence when t is between 0^h and 12^h, $\tan Z$ is negative indicating that Polaris is west of the meridian; and when t is between 12^h and 24^h, $\tan Z$ is positive indicating that Polaris is east of the meridian. In the specimen observations, the suffix 'n' has been added to $\log \frac{1}{1-m}$ thus representing $\log -\left(\frac{1}{1-m}\right)$ in the above formula.

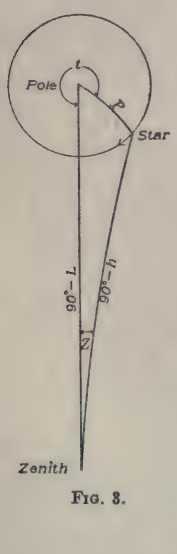


Fig. 8.

By the ordinary formulæ of spherical trigonometry

$$\frac{\sin Z}{\sin t} = -\frac{\sin P}{\cos h}$$

$$\cos Z = \frac{\cos P - \sin h \sin L}{\cos h \cos L}$$

whence $$\tan Z = -\frac{\sin P \cos L \sin t}{\cos P - \sin h \sin L}$$

Eliminating the altitude h by

$$\sin h = \cos P \sin L + \sin P \cos L \cos t$$

after reduction

$$\tan Z = -\frac{\sin t}{\cot P \cos L - \cos t \sin L}$$

which may also be written

$$\tan Z = -\frac{\tan P \sec L \sin t}{1 - \tan P \tan L \cos t}$$

Denoting by a the angle which Polaris makes with the meridian east or west from north, then log a (in seconds) is obtained directly from log tan Z by the use of Table XII, and Polaris is east or west of the meridian according as a is positive or negative.

The logarithms of secant and tangent L are given in Tables IX and X for the north side of every section.

A table giving the Right Ascension and log tan P for Polaris for every ten days, is pasted in each record book of astronomical observations sent out to surveyors.

The observations on pages 36 to 43, one in each quadrant, show the form of record and method of computation.

In the form, R.O. is for reference object; H.C.R. for horizontal circle reading; coll. for collimation; R.A. for right ascension; and F. and B. for forward and backward readings of the microscopes.

The first and second specimen observations are taken on a base line according to the first programme laid down.

The correction for run* of the microscopes in each case is deduced from the means of the forward and backward readings and applied to the forward reading.

The third and fourth specimen observations are observations taken on a meridian according to the micrometric method of the second programme.

It is not necessary that the position of the line of collimation be correctly known. An approximate value may be taken; the bearings of the R.O. deduced from the two sets "circle right" and "circle left", will then differ by

---

*Let F = forward or apparent left reading
B = backward or apparent right reading
Then distance between readings = $5' + F - B$

Error of run = $F-B$

Correction to F = $-F \times \frac{F-B}{5'+F-B}$

Corrected reading = $F \times \frac{5'}{5'+F-B}$

When $F-B$ is not larger than, say, ten seconds, this formula may be written in a more convenient form, without appreciable error. Thus,

Corrected reading = $F - \frac{F}{5}(F-B)$

AZIMUTH OBSERVATION

Place Sta. 68 – 61 chs 52 W. of N.E. cor. sec. 34 Tp. 84-1-5

R. O. Sta. 70 – 60.80 " " " " 33 " "

Date 12-7-11 Observer J. Smith D.L.S.

Position	Pointing No.	Horizontal Circle Readings											
		Reference Object						Polaris					
		Microscope A			Micro. B			Microscope A			Micro. B		
			F.	B.		F.	B.		F.	B.		F.	B.
Circle Right Drum Right	1	359°21'	39"	36"	22'	55"	58"	87°25'	07"	07"	26'	28"	30"
	2		36	37		56	58		08	07		26	32
	3		38	35		54	59		09	07		27	32
Mean		359°21'	37"·1		22'	56"·9		87°25'	08"·0		26'	28"·2	
Circle Left Drum Left	1	179°22'	45"	48"	24'	11"	05"	267°23'	55"	60"	25'	17"	21"
	2		45	48		09	08		58	61		19	21
	3		46	48		11	06		59	60		18	22
Mean		179°22'	46"·8		24'	07"·0		267°23'	59"·7		25'	18"·2	

	Circle Right	Circle Left	
Mean H. C. R. of Pol.	87°25'48"	267°24'39"	Mean watch time
Level correction	+ 5	+ 9	Watch corr.
Corrected H. C. R. of Pol.	87 25 53	267 24 48	Sidereal time
" H. C. R. of R. O.	359 22 17	179 23 27	R. A. of Polaris
Angle Pol. to R. O.	88 03 36W	88 01 21W	t in time
			t in arc
Pol. from collimation log.			Log tan P
One turn micrometer log.			Log tan & sec. L
Altitude Pol. log. sec.			Log cos & sin t
Sum			Sum
Pol. fr. coll. reduced to horiz'al.			Log $-\frac{1}{1-m}$
Level correction			Log tan Z
Microm. angle Pol. fr. coll.			Log T
R. O. from collimation log.			Log a (sec's.)
One turn micrometer log.			Azimuth of Pol.
Altitude R. O. log. sec.			Angle Pol. to R.O.
Sum			Azimuth of R. O.
Microm. angle R. O. from coll.			Mean
Angle Pol. to R. O.			Convergence
			Bearing of R. O.
Direction of deflection		Amount	

FOR GOVERNING SURVEYS

Instrument #112

One turn of micrometer 166".36

One division of striding level 4".0

Watch Time	Micrometer Readings		Level		
	Polaris	R. O.	W.	E.	Corrn.
$5^h\ 34^m\ 16^s$			25·7 6·4	8·1 24·0	+3·4×1·0 ×1·54
			+19·3	-15·9	= + 5"
$5^h\ 43^m\ 46^s$			26·8 6·0	9·0 23·8	+6·0×1·0 ×1·54
			+20·8	-14·8	= +9"

Circle Right		Circle Left	
$5^h\ 34^m\ 16^s$		$5^h\ 43^m\ 46^s$	
+ 6 12		+ 6 12	
5 40 28		5 49 58	
1 27 08		1 27 08	
4 13 20		4 22 50	
63° 20' 00"		65° 42' 30"	
$\bar{2}\cdot31083$	$\bar{2}\cdot31083$	$\bar{2}\cdot31083$	$\bar{2}\cdot31083$
0·17649	0·25622	0·17649	0·25622
T·65205	T·95116	T·61425	T·95974
$\bar{2}\cdot13937$	$\bar{2}\cdot51821$	$\bar{2}\cdot10157$	$\bar{2}\cdot52679$
	0·00603n		0·00552n
	$\bar{2}\cdot52424n$		$\bar{2}\cdot53231n$
	5·31426		5·31426
	3·83850n		3·84657n
	358°05' 05"		358°02' 56"
	88 03 36W		88 01 21W
	270 01 29		270 01 35
			270 01 32
			− 19
			270° 01' 13"

Place Lines re-turn from township corner.

AZIMUTH OBSERVATION

Place. Sta. 76 – 66 chs 71 W of NE. cor. Sec. 33, T. 84-2-5

R. O. Sta. 74 – 74.10 " " " " 34 " "

Date. 20-7-11 Observer. J. Smith, D. J. S.

Position	Pointing No.	Horizontal Circle Readings											
		Reference Object						Polaris					
		Microscope A			Micro. B			Microscope A			Micro. B		
			F.	B.		F.	B.		F.	B.		F.	B.
Circle Right Drum Right	1	359°09'	23"	23"	11'	04"	02"	270°04'	45"	47"	06'	09"	11"
	2		23	25		06	05		45	48		09	11
	3		21	25		05	02		45	50		10	12
Mean		359° 09' 24".0			11' 04".6			270° 04' 48".1			06' 09".7		
Circle Left Drum Left	1	179°10'	17"	15"	11'	47"	50"	90°09'	14"	18"	10'	43"	40"
	2		18	16		49	49		17	18		43	40
	3		17	17		49	50		14	18		43	41
Mean		179° 10' 17".2			11' 48".8			90° 09' 17".6			10' 42".6		

	Circle Right	Circle Left	
Mean H. C. R. of Pol.	270° 05' 29"	90° 10' 00"	Mean watch time
Level correction	+ 1	– 6	Watch corr.
Corrected H. C. R. of Pol.	270 05 30	90 09 54	Sidereal time
H. C. R. of R. O.	359 10 14	179 11 03	R. A. of Polaris
Angle Pol. to R. O.	89 04 44 E	89 01 09 E	t in time
			t in arc
Pol. from collimation ..... log.			Log tan P
One turn micrometer ..... log.			Log tan & sec. L
Altitude Pol. ..... log. sec.			Log cos & sin t
Sum			Sum
Pol. fr. coll. reduced to horiz'al.			Log $-\frac{1}{1-m}$
Level correction			Log tan Z
Microm. angle Pol. fr. coll.			Log T
R. O. from collimation ..... log.			Log a (sec's.)
One turn micrometer ..... log.			Azimuth of Pol.
Altitude R. O. ..... log. sec.			Angle Pol. to R.O.
Sum			Azimuth of R. O.
Microm. angle R. O. from coll...			Mean
Angle Pol. to R. O.			Convergence
			Bearing of R. O.
Direction of deflection		Amount. No correction	

FOR GOVERNING SURVEYS

Instrument #511

One turn of micrometer 164".07

One division of striding level 2".6

Watch Time	Micrometer Readings		Level		
	Polaris	R. O.	W.	E.	Corrn.
$15^h\ 14^m\ 20^s$			34·1 13·6	14·0 33·5	+1·0×0·65 ×1·45
			+20·5	-19·5	= +1"
$15^h\ 22^m\ 04^s$			31·8 15·0	12·0 35·0	-6·2×0·65 ×1·45
			+16·8	-23·0	= -6"

Circle Right		Circle Left	
$15^h\ 14^m\ 20^s$ − 3 15		$15^h\ 22^m\ 04^s$ − 3 15	
15 11 05 1 27 17		15 18 49 1 27 17	
13 43 48 205° 57' 00"		13 51 32 207° 53' 00"	
$\bar{2}\cdot31077$ 0·17649 T·95384n	$\bar{2}\cdot31077$ 0·25622 $\bar{1}\cdot64106n$	$\bar{2}\cdot31077$ 0·17649 T·94640n	$\bar{2}\cdot31077$ 0·25622 T·66994n
$\bar{2}\cdot44110n$	$\bar{2}\cdot20805n$ T·98817n	$\bar{2}\cdot43366n$	$\bar{2}\cdot23693n$ T·98837n
	2·19622 5·31439		$\bar{2}\cdot22530$ 5·31438
	3·51061		3·53968
	0° 54' 00" 89 04 44 E		0° 57' 45" 89 01 09 E
	89 58 44		89 58 54 89 58 49 + 1 05 89° 59' 54"

Place .....

AZIMUTH OBSERVATION

Place Sta. 21 – 35 cho 87 N of N.E. cor. Sec. 13. Tp. 98-1-4

R. O. Sta. 22 – 32.10 " " " " 24 " "

Date 18-7-11 Observer Geo. Norton, D.L.S.

Position	Pointing No.	Horizontal Circle Readings					
		Reference Object			Polaris		
		Microscope A		Micro. B	Microscope A		Micro. B
		F.	B.	F. B.	F.	B.	F. B.
Circle Right Drum Right	1						
	2						
	3						
Mean							
Circle Left Drum Left	1						
	2						
	3						
Mean							

	Circle Right	Circle Left	
Mean H. C. R. of Pol.			Mean watch time
Level correction			Watch corr.
Corrected H. C. R. of Pol.			Sidereal time
" H. C. R. of R. O.			R. A. of Polaris
Angle Pol. to R. O.			t in time
			t in arc
Pol. from collimation log.	$\bar{1}\cdot 63347$	$\bar{1}\cdot 70157$	Log tan P
One turn micrometer log.	$2\cdot 21696$	$2\cdot 21696$	Log tan & sec. L
Altitude Pol. 56° 25' log. sec.	$0\cdot 25716$	$0\cdot 25716$	Log cos & sin t
Sum	$2\cdot 10759$	$2\cdot 17569$	Sum
Pol. fr. coll. reduced to horiz'al	0° 02' 08"	0° 02' 30"	Log $-\frac{t}{1-m}$
Level correction	+ 2	− 5	Log tan Z
Microm. angle Pol. fr. coll.	0 02 10W	0 02 25W	Log T
R. O. from collimation log.	$1\cdot 09127$	$1\cdot 05603$	Log a (sec's.)
One turn micrometer log.	$2\cdot 21696$	$2\cdot 21696$	Azimuth of Pol.
Altitude R. O. 4° 36' log. sec.	$0\cdot 00140$	$0\cdot 00140$	Angle Pol. to R.O.
Sum	$3\cdot 30963$	$3\cdot 27439$	Azimuth of R. O.
Microm. angle R. O. from coll.	0° 34' 00"E	0° 31' 21"E	Mean
Angle Pol. to R. O.	0 36 10E	0 33 46E	Convergence
			Bearing of R. O.
Direction of deflection to the east		Amount 15"	

FOR GOVERNING SURVEYS

Instrument #113

One turn of micrometer 164".80

One division of striding level 3".6

Watch Time	Micrometer Readings		Level		
	Polaris	R. O.	W.	E.	Corrn.
$12^h\ 15^m\ 01^s$	20·471	7·658	22·8	7·0	-1·5 × 0·9
40	·389	·666	7·3	24·0	× 1·52
12 15 20	20·430	7·662	+15·5	-17·0	= − 2"
$12^h\ 19^m\ 37^s$	19·459	31·375	23·1	7·5	+3·4×0·9
20 13	·535	·380	5·8	21·4	× 1·52
12 19 55	19·497	31·377	+17·3	-13·9	= + 5"

Circle Right		Circle Left	
$12^h\ 15^m\ 20^s$		$12^h\ 19^m\ 55^s$	
+ 5 10		+ 5 10	
12 20 30		12 25 05	
1 27 14		1 27 14	
10 53 16		10 57 51	
163° 19' 00"		164° 27' 45"	
$\bar{2}\cdot31079$	$\bar{2}\cdot31079$	$\bar{2}\cdot31079$	$\bar{2}\cdot31079$
$0\cdot19614$	$0\cdot27001$	$0\cdot19614$	$0\cdot27001$
$\bar{1}\cdot98132n$	$\bar{1}\cdot45801$	$\bar{1}\cdot98383n$	$\bar{1}\cdot42793$
$\bar{2}\cdot48825n$	$\bar{2}\cdot03881$	$\bar{2}\cdot49076n$	$\bar{2}\cdot00873$
	$\bar{1}\cdot98684n$		$\bar{1}\cdot98676n$
	$\bar{2}\cdot02565n$		$\bar{3}\cdot99549n$
	$5\cdot31441$		$5\cdot31441$
	$3\cdot34006n$		$3\cdot30990n$
	359° 23' 32"		359° 25' 59"
	36 10E		33 46E
	359 59 42		359 59 45
			359° 59' 44"

Place Sta 21

AZIMUTH OBSERVATION

Place Sta. 30 – 39.78 chs N of N.E cor. Sec 1 Ap 99-1-A

R. O. Sta. 32 – 42.32 " " " " 12 " "

Date 22-7-11 Observer Geo. Norton D. J. S.

Position	Pointing No.	Horizontal Circle Readings											
		Reference Object						Polaris					
		Microscope A			Micro. B			Microscope A			Micro. B		
			F.	B.		F.	B.		F.	B.		F.	B.
Circle Right Drum Right	1												
	2												
	3												
Mean													
Circle Left Drum Left	1												
	2												
	3												
Mean													

	Circle Right	Circle Left	
Mean H. C. R. of Pol.			Mean watch time
Level correction			Watch corr.
Corrected H. C. R. of Pol.			Sidereal time
" H. C. R. of R. O.			R. A. of Polaris
Angle Pol. to R. O.			t in time
			t in arc
Pol. from collimation ..... log.	T·61909	T·75587	Log tan P
One turn micrometer ..... log.	2·21696	2·21696	Log tan & sec. L
Altitude Pol. 58° 44' log. sec.	0·28482	0·28482	Log cos & sin t
Sum	2·12087	2 25765	Sum
Pol. fr. coll. reduced to horiz'al.	0° 02' 12" E	0° 03' 01" E	Log $-\frac{1}{1-m}$
Level correction	+ 8	+ 9	Log tan Z
Microm. angle Pol. fr. coll.	0 02 20 E	0 03 10 E	Log T
R. O. from collimation ..... log.	0·95593	0·89332	Log a (sec's.)
One turn micrometer ..... log.	2·21696	2·21696	Azimuth of Pol.
Altitude R. O. 2° 14' log. sec.	0·00033	0·00033	Angle Pol. to R.O.
Sum	3·17322	3·11061	Azimuth of R. O.
Microm. angle R. O. from coll.	0° 24' 50" W	0° 21' 30" W	Mean
Angle Pol. to R. O.	0 27 10 W	0 24 40 W	Convergence
			Bearing of R. O.
Direction of deflection To the west.		Amount 30"	

FOR GOVERNING SURVEYS

Instrument #113

One turn of micrometer 164".30

One division of striding level 3".6

Watch Time	Micrometer Readings		Level		
	Polaris	R. O.	W.	E.	Corrn.
$0^h\ 43^m\ 11^s$	19·541	29·031	26·5	6·9	+5·4×0·9
53	·627	·039	5·2	22·8	×1·65
0 43 32	19·584	29·035	+21·3	-15·9	= + 8"
$0^h\ 47^m\ 42^s$	20·611	12·175	28·0	10·2	+6·0×0·9
48 21	·529	·181	7·2	25·0	×1·65
0 48 02	20·570	12·178	+20·8	-14·8	= + 9"

Circle Right		Circle Left	
$0^h\ 43^m\ 32^s$		$0^h\ 48^m\ 02^s$	
− 3 32		− 3 32	
0 40 00		0 44 30	
1 27 18		1 27 18	
23 12 42		23 17 12	
348° 10' 30"		349° 18' 00"	
$\bar{2}$·31074	$\bar{2}$·31074	$\bar{2}$·31074	$\bar{2}$·31074
0·19712	0·27071	0·19712	0·27071
$\bar{1}$·99069	$\bar{1}$·31159n	$\bar{1}$·99238	$\bar{1}$·26873n
$\bar{2}$·49855	$\bar{3}$·89304n	$\bar{2}$·50024	$\bar{3}$·85018n
	0·01391n		0·01396n
	$\bar{3}$·90695		$\bar{3}$·86414
	5·31441		5·31442
	3·22136		3·17856
	0° 27' 45"		0° 25' 09"
	27 10W		24 40W
	0 00 35		0 00 29
			0° 00' 32"

Place Sha.30

twice the error of collimation, but the mean of the two will be correct. In the observation the movable thread is assumed to intersect the line of collimation when the drum registers 20·000 turns, which is only approximately correct.

In the position "drum right," the micrometer readings increase as the star travels from right to left, or as the horizontal circle readings decrease. And in the position "drum left," the micrometer readings increase as the star travels from left to right, or as the horizontal circle readings increase. Hence when Polaris is west of the line of collimination, as in the third specimen observation, the level correction is reversed in sign; and when Polaris is east of the line of collimation, as in the fourth specimen observation, the sign of the level correction remains unchanged.

In reducing observations taken on base lines, the convergence must be applied to the mean azimuth to reduce it to a bearing as required by the Manual. For observations taken on initial meridians the results may, for convenience, be left as azimuths.

The correction to the line found from the observation for azimuth may be laid off with the eyepiece micrometer by setting the movable wire the required correction from the middle fixed wire (allowing for the change in value of one turn of the micrometer due to the change of focus of objective from solar focus) and correcting accordingly. Or the surveyor can correct the direction of the line by placing the instrument a certain number of inches from its former position, at right angles to the line. This offset is found by multiplying the distance of the back picket by the tangent of the correction.

CHAPTER II.

THE DETERMINATION OF THE MAGNETIC MERIDIAN.

Although the compass is not allowed for establishing lines of Dominion lands surveys, it is employed for other purposes and a knowledge of the direction of the magnetic meridian or of the magnetic declination is useful. For the determination of this direction, transit theodolites of the D. L. S. pattern are fitted with especially sensitive needles. As the observation can be made in a few minutes and with very little trouble, it is desired that all surveyors should observe whenever they can do so without inconvenience.

The observation and the recording form are arranged for the determination of the azimuth of the magnetic needle instead of the magnetic declination. The arrangement is made for the sake of simplicity in observing and recording, the bearing in question being, subject to instrumental corrections, the angle read on the horizontal circle of the transit. Moreover, it is not liable to errors of sign, as in adding or subtracting the declination.

DIRECTIONS FOR OBSERVING.

1. Place the instrument on a section line, and after adjustment, set the vernier to read the bearing of the line.

2. Release the lower clamp, direct the telescope on the line, and fasten the lower clamp.

3. Release the vernier clamp, and turn the vernier plate until the north end of the magnetic needle observed with a magnifying glass, is seen exactly opposite the zero mark. Tap the trough *lightly with the pencil*, or preferably rit the milled part of one of the footscrews with the finger nail, to be sure that the needle has taken the position of rest. Note the reading of the horizontal circle. Take several readings by repeating the operation.

4. Repeat operation No. 3 for the south end of the needle.

5. Enter in the notes the place of observation, date, hour of the day, kind of time used, nature of the weather and any other remarks deemed necessary. *It is important to record auroras occurring within 24 hours of the time of observation.*

GENERAL REMARKS.

For saving trouble and calculations, it is suggested that observations be made on section lines; they may, however, be made on any line of which the azimuth is known.

The direction of the magnetic needle is subject to a daily fluctuation called the diurnal variation. During the greater part of the night the direction is not far from normal. In the early morning, the north end of the needle in Canada moves toward the east, reaching its maximum deflection about 7 or 8 a.m. The motion is now reversed, the north end travelling westwards, and crossing the normal direction about 10 or 11 a.m. The extreme western position is reached in the afternoon and then the needle comes back to its normal position at some time after 5 or 6 p.m. This march is subject to wide variations during magnetic storms. The magnitude of the diurnal variation is not constant. In the inhabited parts of Canada, it may exceed 20 minutes. Observations at both eastern and western elongations of the needle on the same day, that is between 7 and 8 a.m. and between 1 and 2 p.m., give the best results, and it is desirable that when convenient they may be taken then. This gives not only the best value for the declination, but also the diurnal variation which it is most useful to know. Failing this, however, the best time to observe is after 5 p.m., when the needle is about in its normal position. It is true that the normal position is crossed generally between 10 and 11 a.m., but the motion being very rapid and the time of crossing uncertain, the afternoon observation is preferable.

Usually when instruments are sent out from the office the magnetic needle is balanced for Toronto and the index correction known. If at any time the needle should require rebalancing, the surveyor should proceed as follows:—

Raise the needle with the lifter and remove the brass cover. This cover is secured to the trough by four screws, two on each side; when these screws are removed the cover may be lifted off. Now remove the end cover

glasses. To do this scrape off the white lead putty around the edges, slide the cover glasses toward the centre and lift them out. The needle may now be taken out of the trough and the counterweight shifted. Then the lifter being still raised, place the needle upon it and lower the lifter gently. If the needle is not yet balanced repeat the operation until a satisfactory balance is obtained. A carefully balanced needle should give no parallax in reading.

The steel pivot on which the needle is suspended is tempered glass hard and it is very essential that the needle be lifted completely out of the trough before attempting to move the brass counterweight. Otherwise the pivot point might be broken. For the same reason when sliding back and removing the cover glasses, care should be taken not to jar the pivot cap.

In taking the needle out of the trough whether to rebalance the needle or to clean the agate, care should be taken to see that it is put back in its proper position. If replaced in the reverse position the index correction would be altered. For this reason, to safeguard against error, the position of the compass, whether "compass west" or "compass east" should be entered in the remarks after each observation when observing.

If the needle is sluggish, the observation cannot be accurate. The sluggishness is generally due to a dull pivot or a scratched cap. To keep both in proper condition, *the needle must always be lowered gently on its pivot and never be allowed to play, except when actually in use.*

There are instances of the polarity of the needle being reversed by transporting an instrument on an electric car. It is difficult to conceive that a needle may be brought into such an intense magnetic field as that of an electric car without its magnetism being affected in some way; therefore, it is preferable to avoid this mode of transportation.

The place of observation must be at least three or four hundred yards away from wires carrying direct electric current. There must be no iron near the instrument. The observer must scrutinize his clothing and make sure that he has no iron or nickel on his person. Iron is found in buttons, as wire in hat brims, in some forms of neckties, in watches, chains and other articles of jewellery. The pivot in folding reading glasses is frequently made of iron. In case of doubt, the object may be tried close to the compass, measuring the distance at which an appreciable

deflection is first produced. If the object during the observation is not brought closer than fifteen or twenty times this distance, the effect on the needle is negligible in observations of this kind.

The needle may be deflected by static electricity developed in cleaning the glass cover of the compass trough or the rubber frame of the reading glass: this electricity is dissipated by breathing on the glass or rubber frame.

When the telescope points to magnetic north, the needle should, if the instrument were accurately constructed, be exactly opposite its zero mark, but it seldom is. The deviation of the needle from the zero mark is the *magnetic index correction;* it is positive or + when the north end of the needle is to the left or west of the zero mark; when on the right or east, it is negative or −.

With the needle opposite the zero mark, the telescope points in a direction which, in the following explanations, is called "compass north." To bring the telescope into the direction of the magnetic north, it must, if the index correction is positive, be turned to the right by an angle equal to the correction. Hence the rule that the index correction is to be algebraically added to the azimuth of compass north in order to obtain the azimuth of magnetic north (azimuth reckoned from 0° to 360°). Inversely, the index correction must be algebraically subtracted from the azimuth of magnetic north, such for instance as is taken from a magnetic map, in order to obtain the azimuth of compass north.

The index correction is ascertained by comparison with a standard unifilar magnetometer at the Magnetic Observatory. When possible, it is well to have it determined both at the beginning and at the end of a survey.

EXPLANATION OF SPECIMEN OBSERVATION.

(*a*) H.C.R. of compass north.

This is the average of the mean north and south end readings. The transit was adjusted to read correctly the bearing of the section line, so that the horizontal circle reading of compass north is the bearing of compass north. If the transit had not been so adjusted a correction to this reading would have been required.

(*b*) Correction for convergence.

Form 16.—1-10.

OBSERVATION FOR MAGNETIC DECLINATION

Date 19th July 1908 Observer G.J. Lonergan D.L.S.

Place 40 Chs. W of the N.E. Cor. of Sec. 33

Tp. 49 Rge. 20 W. of 4th Mer.

Time 7.15 p.m. Instrument No. 2216

Bearing of reference line 89°59'

H. C. R. FOR DIRECTION OF MAGNETIC NEEDLE

	NORTH END	SOUTH END
(1)	27° 15'	27° 17'
(2)	11	16
(3)	12	10
(4)	11	10
(5)	10	12
	Mean of North End 27° 11·8	Mean of South End 27° 13·0

(a) H. C. R. of compass north	27°	12·4
(b) Cor. for convergence		−00·6
(c) Azimuth of compass north	27	11·8
(d) Index correction		−058
(e) Azimuth of magnetic north	27	06

REMARKS

A few clouds — Windy.

No aurora.

Circle E — compass W.

Mean local time

The correction for convergence is applied in order to reduce the bearing read on the horizontal circle to an azimuth. The value of the correction is taken from the diagram in the Astronomical Field Tables. It is added when the point of observation is in the east half of the township, and subtracted in the other half. The rule given in the Manual to convert an azimuth to a bearing is here reversed, the object in this case being to convert a bearing to an azimuth.

(*c*) Azimuth of compass north.

The bearing has now been reduced to an azimuth.

(*d*) Index correction.

In the example given, the index correction being negative is subtracted from the azimuth of compass north to obtain the azimuth of magnetic north. If the index correction were positive, it would be added to the azimuth of compass north. The index correction is furnished with each instrument after comparison with the unifilar magnetometer.

(*e*) Azimuth of magnetic north.

The azimuth of magnetic north is the angle formed by the astronomical and magnetic meridians.

SETTING A TRANSIT BY MEANS OF THE COMPASS.

In connection with surveys of Dominion lands, the most frequent use of the compass is for checking the courses of a traverse or for setting up the transit to read azimuths.

In the first case, it is sufficient to make sure that there is no abnormal change in the reading of compass north: any sudden change indicates a probable mistake in some of the last courses.

The second case arises when it is desired to observe the Pole star in day time at a place where there is no line of known azimuth. The problem consists in setting up the transit so that it shall read azimuths. If the surveyor has already ascertained the azimuth of compass north with his instrument, he merely sets his vernier to read this azimuth, releases the lower clamp, turns the whole instrument till the needle is exactly opposite the zero mark, fastens the lower clamp and releases the vernier clamp. With the instrument used for the specimen observation (No. 2216) and anywhere near the place where the observation was taken, the vernier would be set to read 27° 11′·8 or rather 27° 12′.

It may be, however, that the surveyor has not ascertained the azimuth of compass north with his own instrument and has to resort to the azimuth of magnetic north taken from a map or determined by another surveyor. Then the surveyor must, from the azimuth of magnetic north, deduce the azimuth of compass north by applying the index correction of his own instrument after changing the sign. Starting with 27° 06′·0 for azimuth of magnetic north in the case already cited, and the index correction being − 5′·8, the surveyor would add 5′·8 to 27° 06′·0, which would give him 27° 11′·8 for the azimuth of compass north. He would then proceed as already explained.

All these corrections, it may be observed, are generally small and in practice are frequently disregarded.

The above remarks apply particularly to instruments supplied with the trough pattern of compass.

COMPASS OF COOKE TRANSIT.

The Cooke instruments are now fitted with a compass of telescopic pattern which may be briefly described. The outer shell of the compass is a brass tube on one end of which an ordinary Ramsden eyepiece is attached. There is a glass diaphragm on which are etched two close parallel vertical lines. The needle is of the regular edge bar type with one end bent up at right angles and ground to a very fine edge. This end swings sufficiently close to the glass diaphragm to give a good definition of the bent up edge of the needle when the eyepiece is focussed on the lines of the diaphragm. A pointing is made by bisecting the space between the two vertical lines with the needle. Only one end of the needle can of course be read. It is found however that this is more than compensated for by the increased accuracy of the readings. The needle lifter is operated by means of a milled head screw at the end of the compass remote from the eyepiece. The method of fastening this compass to the standard is an improvement on that used with the trough compass and assures better permanency of the index correction.

To rebalance the needle or clean the agate loosen the three small central screws and slide the tube apart. Unscrew the large central screw which ordinarily serves to keep the needle on the pivot. The needle may now be removed for balancing or cleaning. The same precautions and delicacy of handling must be observed as with the trough pattern of compass.

CHAPTER III.

INSTRUMENTS.

The instruments most generally used by Dominion land surveyors are kept in stock at the head office. Some of these instruments are of a special type developed as the result of years of experience to meet the special requirements of Dominion lands surveys.

TRANSIT THEODOLITE FOR GOVERNING SURVEYS.

The instrument for the governing surveys of the system is a six-inch reiterating transit theodolite. The horizontal circle is graduated to five minutes and read by two micrometer-microscopes to five seconds. A four-inch vertical circle read to minutes by a vernier, serves as a finder for stars and for measuring angles of elevation or depression.

The telescope has an object-glass of one and seven-eighths inches aperture and twelve and three-quarters inches focus. It has an eyepiece micrometer, the drum of which is divided into one hundred parts, each representing approximately one and two-thirds seconds. The diaphragm and micrometer can be revolved around the axis of the telescope so as to place the movable thread either horizontal or vertical. Precise level bubbles, electric lamps and special attachments are provided for astronomical observations.

The tripod is of the shifting head pattern for adjusting the instrument accurately over the station. Advantage can be taken of this feature for eliminating the effect of periodic errors of graduation in measuring angles, the instrument being shifted in azimuth so as to use different parts of the graduated circle.

This instrument was designed for the production of lines, the measurement of horizontal angles and the determination of latitudes and azimuths. These are the most important operations in the running of the meridians and base lines which form the governing lines of the Dominion lands system of survey, and with this type of instrument great precision and convenience are obtained.

TRANSIT THEODOLITE FOR SUBDIVISION SURVEYS.

The instrument for subdivision surveys is a repeating four or five-inch transit theodolite, now listed by several firms as "D.L.S." or "Canadian" pattern.

The five-inch transit theodolite, the only kind now supplied, has a five-inch horizontal circle and a four-inch vertical circle. Both circles read to minutes by double opposite verniers. The telescope has a clear aperture of one and one-half inches and a focal length of ten inches. Three eyepieces are supplied; two ordinary inverting of high and medium powers, and one long diagonal. The diaphragm is the ordinary spider web with stadia threads. A spare diaphragm ruled on glass is supplied; it has the disadvantage in star observations of absorbing considerable light.

A trough compass is attached to the standards of the instrument; the needle is very sensitive and it can be adjusted with great precision. It serves for placing the instrument approximately in position for star observations in daylight, for checking the orientation in traverses and for the determination of the magnetic meridian.

A framed tripod is the regular equipment. Sliding tripods or other patterns can be supplied but they are not recommended.

The instrument fits in a leather covered case with shoulder straps, the outside dimensions being about $19\frac{1}{2}$ x $8\frac{1}{2}$ x 8 inches. The weight of the case with the instrument inside is about 27 lbs. The tripod weighs 9 lbs.

SIDEREAL WATCH.

The sidereal watch is an 18 size 19 jewel movement in an open face nickel case. The dial is divided into twenty-four hours.

Before being accepted, each watch is tested at the Surveys laboratory to ascertain if the adjustments have been made with the necessary accuracy. There may be slight changes by the time they reach the surveyors but their accuracy is ample for subdivision surveys.

No timepiece will give good service without reasonable care. Great changes of temperature must be avoided; this is accomplished by carrying it constantly in an inner pocket where it is maintained at an even temperature by

the heat of the body. The pocket must be clean and reserved exclusively for the watch, which is placed in it always in the same position. It is a good plan, as a protection against dust, to keep it in a tight fitting case of chamois skin. If exposed to a very low temperature in winter, it may not only stop, but be injured permanently. It must be kept away from electric motors or dynamos, which might magnetize the balance. Winding every day as nearly as possible at the same hour is essential; this is to be done by turning the crown or the key and not by turning the watch. A watch must be cleaned and oiled at least every fourth year. A watch, particularly if of a higher grade, may easily be ruined by an incompetent workman; too much care cannot be exercised in selecting the man to whom it is entrusted. When any repairs are required, it is best to have them made through the head office.

STEEL TAPES.

The tapes kept in stock are flat wire tapes and quarter-inch steel bands. They are stocked in four, five, and eight-chain lengths. The wire tapes are one-eighth of an inch wide and very strong. Both kinds are divided into links throughout, the graduations being etched. Flat wire tapes with graduations on babbitt metal can also be supplied.

Steel tapes are very liable to break; this fact cannot be impressed too strongly upon the chainmen. In case an accident should happen, the surveyor ought to be provided with means of repair. Fairly good repairs can be made in the field with specially prepared sleeves. The broken ends of the tape are cleaned and inserted into the sleeve and a lighted match is held under it until the solder is melted, when the repair is completed.

Prepared sleeves for flat wire tapes and for quarter-inch tapes are kept in stock.

STADIA RODS.

The stadia rods kept in stock are fourteen feet long and three inches wide. They fold in the middle. They are graduated in links and tenths. There are no figures on the rod, the colour scheme being so arranged that they are unnecessary. A folding level is attached to the back of the rod for holding it vertical.

The stadia wires of the transit theodolite are set by the makers in the supposed ratio of 1:100 between outside wires and 1:200 between middle and outer wires. As a matter of fact however they are never in this exact ratio. The true ratios for each instrument are now determined at the Surveys laboratory and furnished to the surveyor along with the instrument. These ratios are used for calculating a table of the corrections to be applied to the distances read on the rod. If the surveyor should be without the true stadia constants, he can prepare his table of corrections by chaining a base on level ground and measuring with the stadia the distance of a number of points on the base; the difference between the two measurements gives the correction for each distance. The table is completed by interpolation. The measurement must be made when the air is quite steady and the conditions favourable.

CLINOMETER.

The clinometer usually kept in stock is of the pattern known as Abney Level. The angle of elevation or depression is read with a vernier and magnifying glass.

PACKING AND TRANSPORTATION.

Instruments must not be shipped without being packed in outside boxes: if shipped otherwise, there is great risk of injury in transit. For a surveyor's instrument enclosed in a single case, express companies charge three times the merchandise rate, but when the instrument is packed in its own case so that it cannot move and is covered with one or more additional boxes with proper packing or excelsior between, the charge is single merchandise rate. The triple rate will in no case be refunded by the Department to a surveyor who ships an instrument insufficiently packed and he will be held responsible for injuries in transit.

Aneroids and sidereal watches are too delicate to stand transportation by mail or express. These instruments are thoroughly tested at the Surveys laboratory before delivery to surveyors who should arrange to receive them at Ottawa. They will, however, if a surveyor so requests, be forwarded by express packed with the greatest care, but at the surveyor's risk and without any guarantee that they will be in good order when they reach him.

CHAPTER IV.

PROBLEMS CONNECTED WITH THE SYSTEM OF SURVEY.

CORRECTION FOR HEIGHT ABOVE SEA-LEVEL.

The tables have been calculated from the dimensions of the earth's surface at sea-level.

The township sides are actually measured on surfaces elevated above sea-level, and therefore the differences of latitude and longitude calculated from the tables are greater than those actually covered by the township sides.

Any measured distance may be reduced to sea-level by subtracting the correction $\frac{l}{S}x$, x being the distance, l the elevation above sea-level, and S the radius of curvature of the line under consideration.

In general N (see Table I) can be used instead of S.

Base lines when the system of survey is exactly followed are established by direct measurement from the 49th parallel, northward along an initial meridian.

Hence the latitude of a base line should be less than that given in the table by $(L-49°)\ \frac{l}{R}$, where l is the mean elevation of the initial meridian between the 49th parallel and the base under consideration.

Many base lines, however, have been established, not by this direct measurement, but by the survey of township meridians from other bases. If the actual latitudes of these base lines are required, account must be taken of the elevations of all the north and south lines through which the connection with the 49th parallel has been made. It is obvious, however, that the average elevation of the country above the sea will give a sufficiently accurate result, since the small errors due to difference of elevation are masked by errors of survey.

On the base lines the effect of elevation above sea-level is to decrease the difference of longitude covered by one range, and this must be allowed for in establishing an

initial meridian by means of chainage along a base line or in estimating the accuracy of measurement of a base line by its closing on an initial meridian, since the initial meridians, except the first, have been placed approximately on even degrees of longitude (every fourth degree). The longitude covered by one range at an elevation l, may be obtained by multiplying the differences of longitude given in Tables III and IV by $(1 - \frac{l}{N})$.

The correction for elevation above sea-level is, in latitude 51°, 0·00382 chains for one mile distance at an elevation of 1,000 feet, and varies directly as the elevation and distance. It changes somewhat with the latitude, but slightly, and the correction in any particular case may be taken as the same as that for latitude 51°. If extreme accuracy be required, the formula given above, $\frac{l}{S}x$, may be used.

The error in the length of township chords of course involves an error in deflection angles and azimuths, but this is too small to be appreciable.

LATITUDES AND LONGITUDES OF POINTS IN THE SYSTEM.

By "points in the system" is meant the corners of specified sections, or points referred to them by connecting lines. In the latter case the lines, if short, may be reduced to latitude and longitude by means of "latitude and departure" from a traverse table, and by using Table XI.

Thus the problem is reduced to the determination of the latitude and longitude of any section corner.

Latitude.

The latitude of a section corner can be taken directly from Table IX or Table X.

Since the section corners are presumed to be at a distance of even sections from the north and south boundaries of the township, being established by survey from those boundaries, the latitude found as above must, when the section corner is not on the meridian outline of the township, be increased by the correction given by Table XI.

In the first system the sections are not measured on meridians from the north or south boundary of the township, but on lines parallel to the eastern boundary of the township. Hence, theoretically, the difference of latitude between the given corner and the township outline should be decreased in the ratio of cosine azimuth of the section line to unity; but this correction is practically insignificant.

The correction for sea-level may also be applied.

Longitude, Third System.

In the second and third systems, the section lines are true meridians from the base line north and south two townships. Hence the longitude of a section corner is the same as that of the corresponding corner on the base line from which the township has been surveyed.

Then if dM be the longitude covered by one range on that base line, and if n be the number of the range in which the section lies, m the number of sections lying between the given section and the eastern boundary of the township, the number of ranges which intervene between the initial meridian and the eastern boundary of the given section is $n-1+\frac{m}{6}$ and the difference in longitude between it and the initial meridian is $\left(n-1+\frac{m}{6}\right)dM$. This added to the longitude of the initial meridian gives the longitude of the eastern boundary of the section.

The longitude of the Principal or First meridian is 97° 27′ 28″·4.

The longitudes of the Second, Third, Fourth, etc., meridians are 102°, 106°, 110°, etc., subject to certain errors of survey, which cannot be discussed at present.

The difference of longitude should be corrected for height above sea if precision is required. This can be done by multiplying it by $\left(1-\frac{l}{N}\right)$.

For example:

The NE. corner of sec. 16, tp. 23, r. 17, W. of the Fourth meridian (third system of survey). Here $n=17$, $m=3$, and the township is surveyed from the 7th base, for which we find from Table IV, $dM=8'\ 22''\cdot411=502''\cdot411$. Therefore longitude of the section line

$$=110°+(502''\cdot411\times16\tfrac{3}{6})=112°\ 18'\ 09''\cdot78.$$

The NE. corner of sec. 16 is in approximately the same latitude as the NE. corner of sec. 13, and is 3 sections distant from the bounding meridian of the township.

Latitude of NE. cor. sec. 13 tp. 23 (Table X) 50° 57′ 56″·05
Correction for 3 sections (Table XI)..... 0″·07
Latitude of NE. cor. sec. 16 tp. 23.....50° 57′ 56″·12

Longitude, First System.

In the first system the procedure for the longitude is a little different. The section lines are drawn parallel to the east side of the township, so that the difference of longitude between the section line and the east boundary of the township is not the same as on the base line, but is equal to the actual distance from the boundary of the township divided by $P \sin 1''$, $P \sin 1''$ being taken from Table I for the actual latitude of the section post. Thus using the same notation as before

difference of longitude from initial meridian

$$= (n-1)dM + \frac{81 \cdot 50 \times m}{P \sin 1''}$$

dM being taken from Table III (1st system) for the governing base line, or it may be calculated by the equivalent formula

$$\text{difference of longitude} = \left(n - 1 + \frac{m}{6}\right)dM + \frac{Q}{P \sin 1''}$$

where $Q = 2m\,(40 - w)$, w being the width of quarter sections as taken from the last column of Table IX.

Longitude, Second and Fourth Systems.

Longitudes in the second system are calculated in the same way as those in the third, taking dM from Table III instead of Table IV. In the fourth system the process is the same as for the third system, and the same table is used—Table IV.

Effect of Errors of Survey.

An error in the latitude of the base line, or an error in the longitude of the initial meridian, of course increases or decreases by the amount of the error the latitude or longitude

of the section corner. Similarly a chainage error on the base line affects the longitude directly. In the computation all known errors of this kind must be allowed for.

An error in the latitude of the base line also affects the longitude covered by 486 chains (or 489 chains) measured along the base line, since 486 chains covers a greater longitude if the base line be moved north. The manner in which the effect of an error of this kind may be estimated will be best shown by an example.

Suppose the 6th base line (third system) to be placed 10 chains too far north, we find from Table IV

$$\begin{aligned} dM \text{ for 6th base line} &= 498''\cdot662 \\ dM \text{ for 6th correction line} &= 500\ \cdot527 \end{aligned}$$

The 6th correction line is two townships, *i.e.*, 966 chains north of the 6th base line, and the difference in dM for these lines is $1''\cdot865$. Therefore, dM for the actual position of the 6th base line, 10 chains north of its theoretical position, is

$$498''\cdot662+1''\cdot865\times\frac{10}{966}=498''\cdot681$$

The correction, in the case supposed, to dM for one range is $0''\cdot019$, and in 29 ranges (about the distance apart of two initial meridians) it amounts to $0''\cdot019\times29=0''\cdot55$, or 54 links.

GIVEN THE LATITUDE AND LONGITUDE OF A POINT, TO FIND ITS POSITION WITH REGARD TO THE SURVEY SYSTEM, *i.e., to find in what section it is, and the township and range, and its distance from the NE. corner of the section.*

Second, Third and Fourth Systems.

This is the converse of the preceding problem. The first step is to find, from Table IX or X, the latitude of the section line next north of the given latitude. The difference between these two latitudes is reduced to chains by Table I. This gives the distance (x) in chains to be measured from the point to find the north boundary of the section. For great accuracy the small corrections for altitude and from Table XI may be applied to x.

The number of sections by which the section line is north of the southern boundary of the township in which it lies is to be noted. Call this number a, and the number of the township t.

We also know the number of the nearest base line, *i.e.*, the base line on which depends the survey of township t. From Table IV we take out dM for this base line.

From the given longitude of the point subtract the longitude of the initial meridian. Divide the difference by dM, with quotient n and remainder r. Divide r by $\frac{dM}{6}$ with quotient b and remainder s. Then s reduced from seconds of longitude to chains by Table I, with argument, latitude of the given point, gives the distance (y) to be measured east from the point to find the eastern line of the section.

We now know that the given point is x chains south and y chains west of the north-east corner of some section in township No. t and range No. $(n+1)$ west of the initial meridian; and also that the northern boundary of the section is a sections north of the southern boundary of the township, and that the eastern boundary is b sections west of the eastern boundary of the township.

It is now easy by means of a skeleton township diagram to determine the number of the section, *e.g.*, if $a=5$, $b=3$, the section is 28.

Without a township diagram, the section number can be found from the formula

$$\text{No. of section} = \tfrac{1}{2}\{12a-5\pm(2b-5)\}$$

The upper sign is taken when a is odd, and the lower when a is even. These two rules are comprised in the general formula

$$\text{No. of section} = \tfrac{1}{2}\{(12a-5)-(-1)^a(2b-5)\}$$

The calculation for the second system is the same as above, using the proper tables for that system. It is also the same for the fourth system.

In this manner have been computed the positions of a great many section corners in British Columbia (fourth system of survey) with reference to points along the line of the Canadian Pacific Railway, the latitudes and longitudes of these points having been first determined by a traverse survey.

First System of Survey.

The procedure in this system is the same as above, except that the total difference of longitude from the eastern boundary of the township (instead of the nearest section line) must be reduced to chains, and from the distance in chains must be subtracted the nearest multiple of 81·50.

FRACTIONAL TOWNSHIP OR RANGE BETWEEN PARTS OF THE COUNTRY SURVEYED UNDER DIFFERENT SYSTEMS OF SURVEY.

Townships of the first and second systems adjoin each other without overlap or deficiency, since the townships in these two systems are of the same dimensions. Similarly of the third and fourth systems.

But where townships surveyed under the latter systems abut on townships of the first or second system, a fractional township or range occurs. It is only necessary to consider the case of the third system abutting on the first or second, since the fourth does not occur in juxtaposition with these latter systems.

Fractional Township.

Townships of the third system are 6 chains shorter, measured north and south than the others. The townships in both cases are measured north from the 49th parallel, and hence the third system falls short of the other by 6 chains for each township, and the northern boundary of a township of the third system is therefore south of the northern boundary of the same township of the first or second system by 6 chains multiplied by the number of the township.

Thus the 5th correction line (tp. 18), as surveyed under the third system, is $6 \times 18 = 108$ chains south of its position under the second system. For twelve ranges west of the Second meridian, the territory from the 5th correction line northward to the 8th correction line was surveyed under the second system, while the country south of the former line has been surveyed under the third system. There is therefore an additional township (measuring 108 chains from north to south) lying between township 18 of the

third system and township 19 of the second system. (This fractional township is called township 19A, and is subdivided according to the third system. See Manual of Surveys).

Fractional Range.

Townships of the third system are 3 chains narrower (measured east and west along the base line) than those of the first and second systems. The overlap of the latter systems over the third, however, is not equal to 3 chains multiplied by the number of ranges, but exceeds this, since the widths are laid off along base lines which lie in different latitudes, and hence the convergence of meridians comes into play.

The readiest method of calculating this overlap is as follows:—

Let dM_1 be the longitude covered by one range of the base line in the first or second system as found from Table III.

Let dM be the same quantity for the base line of the third system (from Table IV).

Then $dM_1 - dM$ is the difference of the longitude between the exterior meridians of range one, as surveyed under the two systems.

The difference of longitude at the eastern boundary of the nth range will be

$$(n-1)(dM_1-dM)$$

This reduced to chains is

$$(n-1)(dM_1-dM)\ P \sin 1''$$

$P \sin 1''$ being taken from the proper table for the latitude of the base or section line on which the overlap is required.

First Example.

The meridian outline between ranges 12 and 13, west of the Second meridian, from township 19 to township 22, inclusive, is the western boundary of a tract of country surveyed under the second system of survey. Required the width of range 13, as surveyed under the third system, on the northern boundaries of townships 19, 20, 21 and 22.

The base line on which this meridian outline is based, is the 6th base line, or northern boundary of township 20.

From Table III, $dM_1 = 8'\ 21''\cdot 972$
" IV, $dM = 8'\ 18''\cdot 662$

whence $dM_1 - dM = 3''\cdot 310$

and at the eastern boundary of the thirteenth range, the difference of longitude is $3\cdot 310 \times 12 = 39''\cdot 72$

We have then for the northern boundary of township 19 (third system):

Log $39\cdot 72$ =	$1\cdot 5990092$
Table IV, Log $P \sin 1''$ =	$9\cdot 9896352$
	$1\cdot 5886444$
Nat. number =	$38\cdot 783$

For the northern boundary of township 20:

Log $39\cdot 72$ =	$1\cdot 5990092$
Log $P \sin 1''$ =	$9\cdot 9888297$
	$1\cdot 5878389$
Nat. number =	$38\cdot 711$

For the northern boundary of township 21:

Log $39\cdot 72$ =	$1\cdot 5990092$
Log $P \sin 1''$ =	$9\cdot 9880192$
	$1\cdot 5870284$
Nat. number =	$38\cdot 639$

For the northern boundary of township 22:

Log $39\cdot 72$ =	$1\cdot 5990092$
Log $P \sin 1''$ =	$9\cdot 9872086$
	$1\cdot 5862178$
Nat. number =	$38\cdot 567$

Hence townships 19, 20, 21 and 22, surveyed under the third system in range 13, have their eastern tiers of sections narrowed by $38\cdot 783$, $38\cdot 711$, $38\cdot 639$ and $38\cdot 567$ chains respectively, along the north boundaries of the different townships.

Now, the full widths of these sections when regular is got from Table X, by multiplying the "width of quarter section" by 2.

Thus, the width of the eastern tier of sections in range 13 is:

Along N. boundary of tp. 19, $80 \cdot 15 - 38 \cdot 78 = 41 \cdot 37$ chains
" " 20, $80 \cdot 00 - 38 \cdot 71 = 41 \cdot 29$ "
" " 21, $79 \cdot 85 - 38 \cdot 64 = 41 \cdot 21$ "
" " 22, $79 \cdot 69 - 38 \cdot 57 = 41 \cdot 12$ "

These widths must be increased by one chain for road, if the widths from post to post are required.

For the township lines to the north of the correction line, viz.: 23, 24, 25 and 26, the width of range 13 may be found in the same way, using the dM from Tables III and IV for the 7th instead of the 6th base line.

If the width of the fractional section on the north side of the 6th correction line is required, that is, the south boundary of township 23, it must be remembered that here, on account of the correction line being thrown south, from the less depth of the townships of the new system, the southern boundary of township 23 of the third system, which is brought from the 7th base line, intersects the second system south of the correction line, *i.e.*, on a line brought from the 6th base line.

Therefore we have

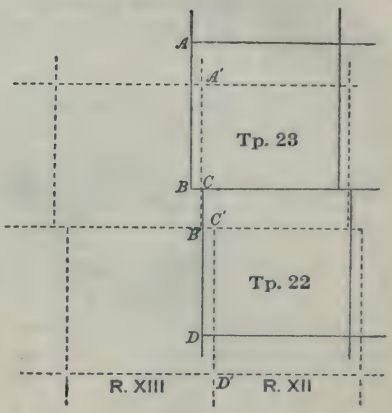
For the second system, Table III, dM_1 6th base $= 8' 21'' \cdot 972$
" third " " IV, dM 7th base $= 8' 22'' \cdot 411$

$$\therefore \quad dM_1 - dM = -0'' \cdot 439$$
and for twelve ranges, $12\,(dM_1 - dM) = -5'' \cdot 268$

With the difference of longitude $5'' \cdot 268$ and the $P \sin 1''$ for the 6th correction line, third system, we get the required jog.

It will be noticed that the overlap is negative, *i.e.*, instead of there being a fractional township there is a surplus.

The heavy lines represent the second system, the dotted ones the third. The line $A'B'$ is the one which we have just considered; it falls to the east of AB, but to the west of CD.



The lines in the figure are all township lines. Thus it will be seen that there is a small piece of land, $B'C$, which is in fact a township of itself. Its designation would be township 23A, range 12A.

Second Example.

Required the depth, north and south, of township 27, range 19, west of the Principal meridian.

The north boundary of township 26 is the northern boundary of a tract of country surveyed under the first system.

Since each township of the third system is 6 chains shorter north and south than one of the first system, the northern boundary of township 26 in the third system is $6 \times 26 = 156$ chains south of the same boundary under the first system.

Therefore the distance from the north boundary of township 26, first system, to the northeast corner of section 12, township 27, third system, is $161 - 156 = 5$ chains.

Since $1 \cdot 50$ chains must be allowed for road, $3 \cdot 50$ chains is the available width of the strip of land.

FRACTIONAL SECTIONS ADJOINING AN INITIAL MERIDIAN.

The longitude of the Principal meridian at the intersection of the 4th base line is 97° 27′ 28″·4.

The Second, Third, etc., meridians were laid down by survey from the Principal meridian, with the intention to place them at every fourth degree of longitude—102°, 106°, 110°, etc. There is also the Second meridian east of the Principal meridian, laid down by survey from it, in approximate longitude 94°.

The actual longitudes, by astronomical observation, of such as have been determined are:

Second meridian at the north boundary of sec. 13, tp. 15, 102° 00′ 16″·5.

Third meridian at the north boundary of sec. 13, tp. 46, 106° 00′ 10″·1.

Fourth meridian at the north boundary of sec. 36, tp. 49, 110° 00′ 18″·0.

Fifth meridian at the north boundary of sec. 36, tp. 52, 114° 00′ 07″·7.

The discrepancies from the intended values are due in part to error in the assumed longitude of the Principal meridian, in part to errors of survey. The longitudes of these meridians at points other than those stated, will of course vary with the azimuthal error in surveying the meridians.

The width of the last range in seconds, on a given base line, when closing on an initial meridian is got by subtracting from the difference in longitude (in seconds) between the initial meridians, the nearest integral multiple of dM from Table III or Table IV (according to the system of survey in question).

Thus for the width of the last range on the 18th base line between the Third and Fourth meridians (third system of survey) we have from Table IV, $dM = 549''\cdot123$ for one range. Assuming the Third and Fourth meridians to be in the above stated longitudes at the 18th base line, we divide the difference of longitude 4° 00′ 07″·9 or 14407″·9 by 549″·123 with quotient 26 and remainder 130″·7. That is, the width of range 27 on the 18th base line or the difference of longitude between the meridian forming the eastern boundary of townships 67, 68, 69 and 70, range 27 and the Fourth meridian is 130″·7.

A better result could be obtained by considering the actual latitude of the base line, and its elevation above sea-level. Thus it is known that the 18th base line between

the Third and Fourth meridians is approximately six chains south of its latitude as given in the tables, and has a mean elevation of about 1,700 feet. Using these figures and proceeding as already explained on pages 56 and 59, correcting for latitude displacement

$$dM = 549'' \cdot 123 - \frac{6}{966} \times 2'' \cdot 365 = 549'' \cdot 108$$

and correcting for altitude

$$dM = 549'' \cdot 108(1 - \frac{l}{N}) = 549'' \cdot 064$$

Proceeding now as before using $549'' \cdot 064$ as the longitude covered by one range we find the width of range 27 to be $132'' \cdot 2$. This difference of longitude can be converted into chains by multiplying by P sin $1''$ for the section line whose length is required, whether the southern boundary of township 67, or the northern boundary of township 70, or any of the intermediate township or section lines.

If the width of the last broken section be required, then if dealing with the third system of survey, integral multiples of $\frac{1}{6}dM$ (difference of longitude covered by one section) must be subtracted from the width of the fractional township until the remainder is less than $\frac{1}{6}dM$. This remainder may then be converted to chains by multiplying by P sin $1''$ taken out of the table for the latitude of the line under consideration. The reason for this is that the widths in seconds of longitude are the same for all sections from the base line to the correction line (second and third systems).

CHAPTER V.

CONSTRUCTION AND USE OF THE TABLES.

The geodetic tables of the Supplement have been based on the dimensions given by Col. Clarke (1866) for the figure of the earth.

In the computation of the tables, no account has been taken of the irregularities and errors of survey, or of the altitude above sea-level at which the surveys are made. The surveys are considered as based on a parallel of latitude of 49°, and the different townships and sections as having their theoretic dimensions.

The tables therefore, do not strictly represent the geodetic quantities for the different points of the Dominion lands system. The method of applying corrections for altitude and known errors of survey is briefly treated on pages 56 and 59. The actual errors of survey and the imperfections of all geodetical assumptions are of too complicated a nature to admit of treatment here.

These discrepancies, however, are always small, and will exert no appreciable influence on the actual field work of a surveyor. With the exception of the latitudes and differences of longitudes, the errors of the tables are indeed entirely negligible.

Table I.

Lengths of Arcs of Meridians, Parallels, etc., in different Latitudes.

According to Col. A. R. Clarke, R.E., in his "Comparison of Standards of Length" (1866), the spheroid of revolution most nearly approaching the form of the earth has for its major or equatorial semi-axis 20926062 feet, and for its minor or polar semi-axis 20855121 feet.

Representing the semi-major and semi-minor axis by a and b respectively, we have for the compression $c=\frac{a-b}{a}=\frac{1}{294\cdot98}$, and the eccentricity e is given by the formula $e^2=\frac{a^2-b^2}{a^2}=0\cdot0067686$.

The unit of measure in the Dominion lands surveys is the Gunter's, or 66-foot chain. The equatorial semi-axis in chains is 317061·545.

Representing by L the geographical latitude of a place, or the angle which its vertical line makes with the plane of the equator, we have for the radius of curvature of the meridian

$$R=\frac{a(1-e^2)}{(1-e^2\ \sin^2\ L)^{\frac{3}{2}}},$$

for the length of the normal to the meridian terminated by the minor axis

$$N=\frac{a}{(1-e^2\ \sin^2\ L)^{\frac{1}{2}}},$$

and for the radius of the parallel of latitude L

$$P=N\ \cos\ L.$$

The length in chains of one second of latitude is equal to R sin 1″; one second of the great circle perpendicular to the meridian is equal to N sin 1″; and one second of longitude is equal to P sin 1″. The logarithms of these quantities are placed in the second, third and fourth columns of Table I. They have been calculated by means of the logarithmic expansions of R and N.

Thus putting n for $\frac{a-b}{a+b}$ we have

$$\log\ (R\ \sin\ 1'')=\log\ [a(1-n)^2(1+n)\ \sin\ 1''] \\ -3\mu n\ \cos\ 2L\ +\ \tfrac{3}{2}\ \mu n^2\ \cos\ 4L-\text{etc.}$$

where μ is the modulus of the common system of logarithms, and powers of n higher than the second are neglected as being insensible in the eighth decimal place.

Substituting the value of a in chains, as given above, and taking

$$n=\frac{a-b}{a+b}=\frac{1}{588\cdot 96},\ \text{we get}$$

$$\log\ (R\ \sin\ 1'')=0\cdot 18597916-0\cdot 00221218\ \cos\ 2L \\ +0\cdot 00000188\ \cos\ 4L.$$

In calculating the last two terms by logarithms five places are sufficient.

For $N \sin 1''$ we have

$$\log (N \sin 1'') = \tfrac{1}{3} \log (R \sin 1'') + \tfrac{2}{3}\{\log a + \log \sin 1'' + 2\mu n\}$$
$$= \tfrac{1}{3} \log (R \sin 1'') + 0 \cdot 12546215.$$

For $P \sin 1''$

$$\log (P \sin 1'') = \log (N \sin 1'') + \log \cos L$$

The calculation has been made to eight places of decimals to ensure accuracy in the seventh place. In tabulating, the eighth figure has been dropped.

The calculation of the logarithms of $R \sin 1''$ and $N \sin 1''$ has also been made directly from the formulæ for R and N, by the use of a subsidiary angle.

Thus, finding an angle ψ such that $\sin \psi = e \sin L$, we have

$$R \sin 1'' = a(1-e^2) \sec^3 \psi \sin 1''$$
$$N \sin 1'' = a \sec \psi \sin 1''$$

Seven figure logarithms were used, and consequently the results could not be depended upon to the seventh figure, but they have been serviceable as a check upon the series computation.

Log $N \sin 1''$, log $P \sin 1''$ and log $R \sin 1''$ are given in the table for every 10′ of latitude from 42° to 70°. Their values for intermediate latitudes can be obtained by simple interpolation. Where, however, log $P \sin 1''$ is required with accuracy for an intermediate latitude, it is better first to obtain log $N \sin 1''$ for that latitude by interpolation from the table and then to add log cos L.

Under the heading "Chains in 1″" are given the natural numbers corresponding to the logarithms of $R \sin 1''$ and $P \sin 1''$. These natural numbers are useful in reducing small differences of latitude and longitude to chains by simple multiplication, being preferable in many cases to the logarithms.

The converse operation of reducing short distances north and south or east and west to seconds of latitude or longitude may be performed by multiplying by the quantities in the two columns headed "Seconds in one Chain." These columns contain the reciprocals of the quantities in the columns "Chains in 1″."

In the last two columns of the table are given the lengths of one degree of latitude and longitude in English miles.

Radius of Curvature of a Section of the Spheroid inclined at any angle to a Meridian.

In some operations it is necessary to find the radius of curvature of the trace on the earth's surface of a "straight" or "transit" line, making a given angle with the meridian.

Representing this radius of curvature by S, and θ being the angle with the meridian, we have the formula

$$\frac{1}{S}=\frac{\cos^2\theta}{R}+\frac{\sin^2\theta}{N}$$

and introducing an auxiliary angle X determined by the formula

$$\tan X=\sqrt{\frac{R\sin 1''}{N\sin 1''}}\tan\theta, \text{ we have}$$

$$S\sin 1''=N\sin 1''\frac{\sin^2 X}{\sin^2\theta}$$

a formula adapted for ready calculation by means of logarithms.

Radius of Spherical Curvature.

The mean of the values of S when θ is given all possible values is $\sqrt{NR}$. This is the radius of curvature of the surface or the radius of the sphere to the surface at a given point. Its logarithm is readily found from Table I, being the arithmetical mean of the logarithms of N and R.

Table II.

Corrections to Table I for change in Elements of Figure of Earth.

In Table I the data used are Clarke's 1866 values, viz.:—

$$a=20926062 \text{ feet}$$

$$n=\frac{1}{588\cdot 96}$$

and all the following tables are based on Table I, and therefore on these values. Clarke's later values (Geodesy, 1880) are,

$$a=20926202 \text{ feet}$$

$$n=\frac{1}{585\cdot 93}$$

If, for any purpose, it is desired to use these values, Table I can be corrected by means of Table II, which has been computed thus:

Differentiating the formulæ,

$$\log R \sin 1'' = \log a + \log \sin 1'' - \mu(n + \tfrac{3}{2}n^2) - 3\mu n \cos 2L + \tfrac{3}{2}\mu n^2 \cos 4L$$

$$\log N \sin 1'' = \log a + \log \sin 1'' + \mu(n - \tfrac{1}{2}n^2) - \mu n \cos 2L + \tfrac{1}{2}\mu n^2 \cos 4L$$

and putting $\frac{1}{n} = p$, we have

$$d(\log R \sin 1'') = \mu\frac{da}{a} + \mu n^2 dp + 3\mu n^2 \cos 2L dp$$

$$d(\log N \sin 1'') = \mu\frac{da}{a} - \mu n^2 dp + \mu n^2 \cos 2L dp$$

μ being the modulus of the common system of logarithms. Terms involving the cubes and higher powers of n are insensible and may be neglected.

To change Clarke's earlier to his later values, we have

$$da = +140 \text{ (feet)}$$
$$dp = -3 \cdot 024$$
$$a = 20926062 \text{ (feet)}$$
$$n = \frac{1}{588 \cdot 96}$$
$$\text{and } \mu = 0 \cdot 43429448$$

whence $d \log (R \sin 1'') = - \cdot 00000088 - \cdot 00001136 \cos 2L$

$$d \log (N \sin 1'') = + \cdot 00000669 - \cdot 00000379 \cos 2L$$

These quantities are tabulated in Table II, with the proper signs of application to $\log R \sin 1''$ and $\log N \sin 1''$ in Table I.

Table III.

Latitudes of Base and Correction Lines and Lengths of Arcs of Meridians, Parallels, etc., for First and Second Systems of Survey.

This table is constructed for the first and second systems of survey only. It accordingly stops at the 13th base, township 48, north of which there are no surveys under these systems.

Each township measuring 489 chains each way, the 1st correction line is 978 chains north of the 49th parallel.

The latitude of the 1st correction line is therefore

$$49° + \frac{978}{R \sin 1''}$$

Here $R \sin 1''$ must be taken from Table I for the middle latitude between the 1st base and the 1st correction line. For accuracy it is therefore necessary to compute an approximate difference of latitude, using an approximate value of $R \sin 1''$. For instance $R \sin 1''$ may be taken from the table for latitude 49°.

The approximate difference of latitude being thus determined, the middle latitude is found from it (this being a sufficiently close approximation), and the final $R \sin 1''$ is taken from Table I for that latitude. Then dividing 978 by this we have a very close approximation to the difference of latitude between the base and the correction line.

From the latitude thus obtained of the 1st correction line, that of the 2nd base line is found by a similar process, and so on in succession as far as the table extends.

The table is checked by applying the same process to a longer distance than 978 chains. For example, the latitude of the 6th base can be directly determined from that of the first by using 9,780 chains instead of 978. When long distances are thus taken, a second approximation to the middle latitude may become necessary.

The columns $\log N \sin 1''$ and $\log R \sin 1''$ are taken from Table I by interpolation, and $\log P \sin 1''$ is found by adding $\log \cos L$ to $\log N \sin 1''$.

The width of a township along a base line is 489 chains. The longitude corresponding to this length measured along the parallel of latitude is given in the column headed "Longitude covered by 489 chains of westing," not only for the base lines but also for the correction lines.

The longitude for 489 chains, along a base line, is the longitude covered by one range of townships. Along a correction line it does not correspond to the longitude covered by a range, since the width of a township along a correction line is greater or less than 489 chains according as the township north or south of the correction line is considered. The tabulated quantity, however, for correction lines can be used to calculate the narrowing or widening of sections at the correction lines.

The township width 489 chains is measured along the base line which has such azimuth that its terminal point falls in the same latitude as its initial point.

Thus every township corner along a base line has the same latitude, and the base line is a succession of chords of the latitude circle.

The difference of longitude between one township corner and the next is given by the formula

$$dM = \frac{489}{P \sin 1''}$$

It is assumed here that the chord of the arc of the latitude circle is equal to the arc. That the difference between the chord and the arc is inappreciable may be shown thus:

By spherical trigonometry

$$\sin \frac{\text{chord}}{2N} = \sin \frac{dM}{2} \cos L$$

$$\text{whence chord} = N \cos L \, dM - N \cos L \sin^2 L \, \frac{dM^3}{24}$$

$$= \text{arc} - \text{arc} \times \frac{dM^2}{24} \sin^2 L$$

So that the difference between the chord and the arc is equal to

$$\text{arc} \times \frac{dM^2}{24} \sin^2 L$$

dM being in circular measure.

For any township chord this amounts to less than one fiftieth of a link.

The chord always lies north of the arc. The distance between them is greatest at their middle points, amounting there to about 10 links. Hence, at the international boundary line, which is the first base line, since the actual

territorial boundary is the curve, and the base line a series of chords, the road allowance which lies along the north side of this base is increased in width by 10 links at the middle of the chords.

The non-coincidence of the chord and arc also has the effect of increasing and decreasing the widths of roads on correction lines, since on account of the jog, the township corners north and south of the road are not opposite one another. The increase or decrease in the width of the road along correction lines, when required, may be easily found by an application of Table XI.

In the first column of Table III are given, for convenience, the numbers of the townships corresponding to the several base and correction lines. Thus the 6th base is the northern boundary of township 20, and so on.

Table IV.

Latitudes of Base and Correction Lines, etc., for Third and Fourth Systems of Survey.

This table is exactly similar to Table III, except that it is made for the third system of survey, where the widths of townships are 486 instead of 489 chains, and their depths, in a north and south direction, 483 instead of 489 chains.

This table also applies, without change, to the fourth system (British Columbia).

In this table, as well as in Table III, the latitudes given are those of the line of posts on the south side of the road allowance. To get the latitude of the posts north of the road on correction lines, the latitude of the correction line, as given in the table, must be corrected by adding the equivalent in latitude of the width of the road, *i.e.*, one chain and a-half for the first and second systems (Table III), and one chain for the third system (Table IV).

Table V.

Chord Azimuths, etc., for Base Lines, First and Second Systems of Survey.

The extremities of the township chord, as above stated, are in the same latitude. Hence the chord is equally inclined to the meridians passing through its terminal

points, and its azimuth, east or west of north, is equal to the complement of half the change in azimuth, that is, of half the "convergence of meridians."

Let dZ represent the change in azimuth or convergence of meridians, dM the difference of longitude, and L the latitude.

Then, by spherical trigonometry,

$$\tan \tfrac{1}{2}\, dZ = \tan \tfrac{1}{2}\, dM \sin L$$

whence, by expansion of the tangents in terms of the arcs,

$$dZ = dM \sin L + \frac{dM^3}{12} \sin L \cos^2 L$$

or, if dZ and dM be expressed in seconds,

$$dZ = dM \sin L + \frac{dM^3}{12} \sin L \cos^2 L \sin^2 1''$$

The second term is inappreciable, amounting in latitude 51° to less than one ten-thousandth of a second.

$$\therefore dZ = dM \sin L$$

The convergence or "deflection" (dZ), given in Table V, is thus calculated from the difference of longitude (dM) in Table III.

The "chord azimuth" is the complement of half the deflection.

The chord azimuth and the deflection are given in the table in degrees, minutes and seconds, as well as in decimals of a degree, for sexagesimally and decimally divided instruments respectively.

In the survey of a base line, the surveyor, when he arrives at a township corner, deflects his line to the north through an angle equal to the "deflection," and thus establishes in azimuth the chord across the next range of townships.

This deflection angle may be turned with the instrument, but more readily by the use of the "deflection offsets" in the table. The tabulated offset is the linear distance in inches between one of the chords and the prolongation of the other, at one chain from the township corner.

Their distance apart at any point is found by multiplying the tabulated offset by the distance, expressed in chains, of the point from the township corner.

For example, if the instrument is standing on the prolongation of the first chord at 5 chains past the corner, and the back picket be 15 chains on the other side of, that is, behind

the corner, then the instrument must be moved north five times, and the back picket south fifteen times, the "deflection offset for one chain." The line of the instrument and picket is now in the correct bearing for the prolongation of the base line.

The angle is thus turned as accurately as a straight line can be produced with the instrument, and much more accurately than the angle can be measured with the graduated arc, while the setting of the instrument at the corner (which may be in low ground, unsuitable for accurate line production) is rendered unnecessary.

"Longitude covered by one range" in the seventh column is merely the longitude in the seventh column of Table III, reduced to time by dividing by 15. This gives the number of seconds which a watch will gain or lose on local time in being carried across a range. The gain or loss in travelling over any other distance along the base line is proportional to the distance. The column is added for astronomical purposes, especially the determination of azimuth by observation of Polaris at any hour angle.

This Table V applies to the first and second systems of survey.

Table VI.

Chord Azimuths, etc., for Base Lines, Third and Fourth Systems of Survey.

This table is exactly similar to Table V, but is made for the third system of survey.

The calculation is made by the same formulæ, changing only the width of the range, which is 486 instead of 489 chains, and using the latitudes of the base lines from Table IV, instead of those from Table III.

$$dM = \frac{486}{P \sin 1''}, \qquad dZ = dM \sin L$$

This table also applies to the fourth system.

Table VII.

Chord Azimuths, Jogs, etc., for Correction Lines, First and Second Systems of Survey.

This table gives quantities for correction lines similar to those given in Table V for base lines. This table applies to the first and second systems of survey.

The correction lines are posted on both sides of the road. The chord azimuths and deflections are given for the south side of the road, which is that side for which the latitudes of correction lines are given in Table III.

The calculation of the chord azimuth for correction lines is somewhat different from that for base lines.

For the base lines we have

$$dM = \frac{489}{P \sin 1''}$$

$$\text{deflection} = dM \sin L$$

For the correction lines, one range is not 489 chains, but the distance between meridians which include 489 chains on the nearest base line.

Hence in the formulæ—

$$dM = \frac{489}{P \sin 1''}$$

$$\text{and deflection} = dM \sin L = \frac{489}{P \sin 1''} \sin L$$

we must take $P \sin 1''$ for the next base line south of the correction line, if the difference of longitude and the deflection for the south side of the correction line road are required; while for the north side of that road we must take $P \sin 1''$ for the next base line north. L of course, is the latitude of the correction line itself.

The length of one range on the correction line is $dM \times P \sin 1''$.

If, then, P_1 and P_2 represent the radii of parallels for the base lines next north and south, respectively, P that for the correction line itself

$$dM_1 = \frac{489}{P_1 \sin 1''}$$

$$dM_2 = \frac{489}{P_2 \sin 1''}$$

and we have for the length of one range on the correction line

$$\text{North side} = \frac{489}{P_1 \sin 1''} \times P \sin 1''$$

$$\text{South side} = \frac{489}{P_2 \sin 1''} \times P \sin 1''$$

The values of these quantities are tabulated in the seventh and eighth columns of Table VII.

For extreme accuracy $P \sin 1''$ for the north side of the road should be taken out for a latitude greater by 1·50 chains, or 0″·98 greater than that tabulated in Table III; but the difference in the result would be almost inappreciable, being less than one quarter of a link per township.

The difference of lengths of the township lines north and south of the correction line road gives the overlap or jog.

The jog for one range is given in the ninth column of the table. As this jog occurs in each range of townships, its value at any range is the product of the jog for one range by the number of ranges.

The excess of the length of the north side over, or the defect of the south side from 489 chains, is the linear divergence or convergence of the township lines. Since there are twelve half sections in a township side, the convergence or divergence for one half section is one-twelfth of the convergence or divergence for the township, or one twenty-fourth of the jog, the excess of the north side and the defect of the south side being very nearly, though not quite, equal.

This convergence or divergence for one half section is entered in the tenth column of the table. It is used in the second system, where the surplus or deficiency caused by the convergence of meridians is divided equally among all the quarter-sections. Hence, in surveying a correction line under the second system, the width of each quarter section (exclusive of the roads) is forty chains *plus* or *minus* this tabulated quantity. The surplus or deficiency on the township line midway between the base and the correction line is half of that on the correction line.

In the first system the whole of the surplus or deficiency is thrown into the western tier of quarter sections. This surplus or deficiency is the difference between 489 chains and the quantities in the seventh and eighth columns of Table VII. For example, on the north side of the road on the 1st correction line the surplus is 1·75 chains, and the westerly quarter section of the township is therefore 41·75, all the others being 40 chains.

It is to be observed that in all cases the whole divergence or convergence is applied to the section itself, and that the road allowance retains its width of 1 chain or 1½ chains, with the exception of the roads on correction lines, which are subject to a widening or narrowing as explained under Table III.

Table VIII.

Chord Azimuths, Jogs, etc., for Correction Lines, Third and Fourth Systems of Survey.

This table gives for the third and fourth systems the same quantities as are given in Table VII for the first and second systems.

The surplus or deficiency is in all cases divided equally among all the quarter sections.

Table IX.

Latitudes, and Widths in Chains, of Northern Boundaries of Sections in First and Second Systems of Survey.

This table, with Table XI, gives the latitudes in degrees, minutes and seconds for the northern boundaries of all sections in the first and second systems.

The sections numbered in the second column are those adjacent to the eastern boundary of the township. The latitudes of the northern boundaries of interior sections lying west of these are approximately the same. Thus the northern boundaries of sections 14, 15, 16, 17 and 18 have very nearly the same latitude as the north boundary of 13, and so for the other east and west tiers of sections. The small corrections required to the latitudes of Tables IX and X to obtain the latitudes of the northeast corners of sections not on the bounding meridians of townships are given in Table XI.

These latitudes are computed by interpolating from the latitudes given in Table III.

The logarithmic secant and tangent of the latitude are given in the table for use in calculation of azimuth observations.

In the last column of the table are given the widths of the north boundaries of the quarter sections (in the second system of survey). These are calculated for the correction lines in the manner explained under Table VII, and for the intermediate lines by interpolation.

For quarter sections adjoining correction lines the usual width is given for the north boundary of the quarter section to the south of the correction line; bracketed with it is also given the width, measured along the south boundary, of the quarter section immediately to the north. That is, the two lengths bracketed are the lengths of quarter section sides measured along the south limit and the north limit, respectively, of the road on correction lines.

Table X.

Latitudes, and Widths in Chains, of Northern Boundaries of Sections in Third and Fourth Systems of Survey.

This table gives for the third system the same quantities as are given in Table IX for the first and second.

The table may also be applied to the fourth system by correcting the latitudes of the alternate section lines, viz., the north boundaries of sections 1, 13 and 25 in each township, by subtracting therefrom $0''\cdot33$, the equivalent in arc of 50 links. The change in the logarithmic secant and tangent is inappreciable, as these logarithms are given to only five places of decimals. The widths of quarter sections in the last column must be increased by 50 links.

Table XI.

Difference of Latitude between Township Corners and Section and Quarter Section Corners.

This table is used when it is required to find accurately the latitude of any point on a township chord or within a township, as when it is desired by connecting with an astronomically determined latitude point to find the error of the survey lines.

If Z be the initial azimuth of the township chord, Z_1 its azimuth at a distance x from the corner of the township, L the latitude of the township corner, L_1 the latitude of a point on the chord distant x from the corner.

Then by spherical trigonometry,

$$\frac{\cos L_1}{\cos L} = \frac{\sin Z}{\sin Z_1}$$

whence $$\tan \frac{L_1 - L}{2} \tan \frac{L_1 + L}{2} = \tan \frac{Z_1 - Z}{2} \cot \frac{Z_1 + Z}{2}$$

putting $$Z = \tfrac{1}{2}(\pi - \theta)$$
$$Z_1 = \tfrac{1}{2}(\pi - \theta_1)$$

where θ and θ_1 are expressed in circular measure, and are very small, so that their cubes may be neglected. Also $L_1 - L$ is very small, and $L_1 + L$ is very nearly equal to $2L$.

Then $$L_1 - L = \frac{\theta - \theta_1}{2} \cdot \frac{\theta + \theta_1}{4} \cot L = \frac{\theta^2 - \theta_1^2}{8} \cot L$$

and θ = convergence of meridians for one township chord;

$\therefore \theta = \frac{c}{N} \tan L$, c being the length of the chord, and $\frac{\theta_1}{\theta} = \frac{c - 2x}{c}$,

whence $$\theta^2 - \theta_1^2 = \frac{4(c-x)x}{c^2} \theta^2$$

Therefore $$L_1 - L = \frac{(c-x)x}{2N^2} \tan L$$

or difference of latitude in chains

$$= R(L_1 - L) = \frac{Rx}{2N^2} (c - x) \tan L$$

The computation has been made for the third system of survey, but may be used for any system without sensible error.

Table XII.

For Converting Logarithmic Tangents of Small Arcs into Logarithms of Seconds of Arc.

This gives the logarithm of the ratio of a small arc expressed in seconds of arc, to its tangent; by adding it to the log tangent, the logarithm of the arc is obtained, and the arc itself is found with a table of logarithms of numbers, without having to compute proportional parts.

92081—6½

Table XIII.

$$Log \frac{1}{1-m}$$

These tables are useful in abridging the work of reduction of time-azimuth observations on Polaris; they give at once the value of $\log \frac{1}{1-\tan P \tan L \cos t}$ when $\log \tan P \tan L \cos t$ is known. The quantity $\tan P \tan L \cos t$ has been represented by m, so that the azimuth formula may be written

$$\tan Z = -\frac{1}{1-m} \tan P \sec L \sin t$$

It will be noticed that $\log \frac{1}{1-m}$ must be taken out with regard to the sign of m, using the part of the table on pages 146, 148 and 150 when m is positive, and the part on pages 147, 149 and 151 when m is negative. Hence, since the sign of m is the same as that of $\cos t$, the part of the table as given on pages 146, 148 and 150 is to be used when t, the hour angle of Polaris, lies between 0^h and 6^h or between 18^h and 24^h; and the part of the table as given on pages 147, 149 and 151 is to be used when t lies between 6^h and 18^h.

Table XIV.

Deflection of a Trial Line for Deviations from 1 to 149 Links at the end of Eighty-one Chains.

This is useful in deflecting trial lines. It gives the angular deflection of a line for deviations of 1 to 149 links at the end of eighty-one chains.

Table XV.

To Reduce Chains to Decimals of a Township Side.

This is a short table giving the equivalents of chained distances in terms of a township side, for township sides of the first and second systems (489 chains), for east and west lines of the third and fourth systems (486 chains) and for north and south lines of these last systems (483 chains). The table is useful in calculating the difference in azimuth of an east or west line between a township corner and any other point upon it, and for similar purposes.

Table XVI.

Corrections in Links to Slope Measurements.

This table has been computed for the use of surveyors working in mountainous country where the slopes are measured with the transit; it is not well adapted to ordinary clinometer chaining.

The table has been compiled with the correction as argument, to give an accuracy of one-tenth of a link per chain. A greater degree of accuracy may, of course, be obtained by interpolation to the measured slope, but it is seldom necessary. The corrections are given for every chain length up to nine chains, the object being to simplify the surveyor's calculation in the field. A convenient method of using the tables is illustrated by the following example.

Required the slope correction for 3·682 chains at 26°09′.

This slope lies between the tabulated slopes 26°06′ and 26°14′. Taking out the slope corrections for a slope of 26°06′ and the differences of the corrections for 26°14′ and 26°06′:

Correc. for 3	chs.	= 30·6	lks.	with diff. for 8′	of	0·3	lks.
" 0·6	"	= 6·12	"	"	"	0·06	"
" 0·08	"	= 0·82	"	"	"	0·01	"
" 3·68	"	= 37·54	"	"	"	0·37	"

Difference for 3′ is $\frac{3}{8} \times 0 \cdot 37 = 0 \cdot 14$ lks.

Correc. for 3·68 chs. at 26°09′ = 37·54 + 0·14 = 37·68 lks.
= 0·377 chs.

Table XVII.

Table for Laying Out Roads One Chain Wide.

This table is intended for laying out roads; it gives for roads one chain wide the distance to the opposite limit at road corners when the survey is made along one of the limits. For wider or narrower roads, the tabular distance is proportionally increased or decreased. When the survey is made along the middle of the road, the distance of the corners on each side is one half of the tabular distance, as explained in the Manual of Instructions for the Survey of Dominion Lands.

THE ASTRONOMICAL FIELD TABLES.

DESCRIPTION OF THE TABLES.

The Field Tables are now issued in two sets—giving data for sun observations and for star observations respectively. There is also printed on cards of pocket size, a diagrammatic map of Western Canada showing the general disposition of the isogonic lines for each degree. Both the tables and the map should be in the hands of all surveyors engaged on Dominion lands surveys.

The Field Tables for solar observations are issued each year. They give the sun's apparent declination at Greenwich mean noon with its variation for one hour, and the sun's apparent right ascension at Greenwich apparent noon with its variation for one hour. These data, which are taken direct from the Nautical Almanac, are tabulated for every day of the year. There is also a table of mean refraction for different altitudes with the corrections required thereto for temperature and barometric pressure.

The sun's declination and the refraction tables are required for observations on the sun for azimuth; the sun's right ascension for obtaining the sidereal time by observing the meridian transit of the sun. For both these purposes the approximate longitude is required; if not known, it may be conveniently taken with sufficient accuracy from the diagram in the Field Tables for star observations.

Full instructions for solar observing with specimen observations are given in Chapter I.

The Field Tables for star observations are issued for short periods in different years. They contain a table for finding the Pole star and the astronomical meridian, a list of "time stars," the sidereal time at mean noon, mountain time, for the 15th of each month, and diagrams showing the approximate longitude, latitude and convergence of meridians over one section for points of the Dominion lands system.

Table for Finding the Pole Star and the Astronomical Meridian.—The table is entered with the sidereal time as argument. The first column gives the number of minutes to be added to or subtracted from the latitude to obtain

the altitude of the star. In the second column is the argument, the local sidereal time for every ten minutes. In the other columns is the azimuth of the star for every twentieth township up to township 140. The table enables the Pole star to be readily found in day time, and when found and observed, provides an easy means of determining its bearing. When the position of the astronomical meridian is known approximately, as is the case on subdivision surveys, the transit instrument can be set in the direction of the star and to the proper altitude by means of the table. When it is not known, however, recourse may be had to the map showing "Azimuth of Magnetic North in Western Canada" furnished to surveyors on request. With a D.L.S. transit, the vernier of the horizontal circle is set to read the azimuth of magnetic north, the lower clamp is released and the instrument turned in azimuth until the points of the compass needle coincide with the index marks. The lower clamp being now fastened and the vernier plate released, the readings of the horizontal circle are approximately astronomical azimuths. The index correction of the surveyor's compass, which is furnished him at the commencement of each season, should be allowed for.

The method of observing and use of the tables are fully explained in Chapter I. The Field Tables are not absolutely accurate, but the precision is ample for subdivision surveys.

Time Stars—The exact local sidereal time and the error of the watch may be obtained by observing the meridian transit of a "time star." The star Field Tables give a list of time stars suitable for Dominion lands survey work. In the last column is found the approximate polar distance of each star, from which its altitude at transit is calculated for setting the telescope. The list gives the sidereal time of meridian transit of each star for each month covered by the tables. This data is taken from the Nautical Almanac.

Sidereal Time at Noon, Mountain Time.—This table gives the approximate sidereal time at noon, mountain time, for the 15th of each month. It provides a first approximation for setting the surveyor's watch from standard time clocks.

Longitude in Hours and Tenths.—From this diagram the longitude in hours and tenths can be readily obtained. The approximate longitude is required for the interpolation of the sun's apparent right ascension and declination in solar observations.

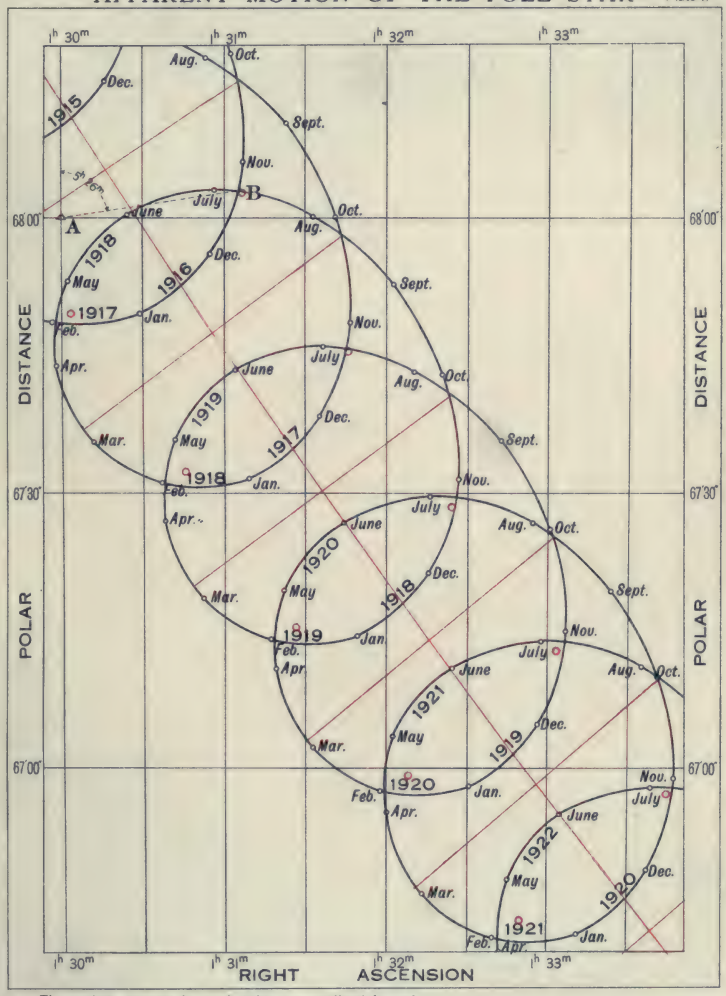
Latitude and Convergence per Section.—The diagram shows at a glance for every township up to township 140, the approximate latitude and the convergence of the meridians for one section in minutes and hundredths. The latitude is used as previously mentioned for calculating the altitude of stars for daylight observations. The convergence serves to refer an observed azimuth to the meridian of the centre of the township or to any other meridian, as explained in the Manual of Survey.

THE APPARENT MOTION OF POLARIS.

The path described by the Pole star on the celestial sphere from 1916 to 1922 is shown on Plate II. It is the combined effect of precession, nutation, aberration and proper motion. This constant variation in the position of the star produces a slow change in the azimuth from any point, irrespective of the daily variation of azimuth caused by the earth's rotation. Hence at the same sidereal time on two successive days the star will not have quite the same azimuth. If the azimuth of the star be considered at the same sidereal time each day for a month, there will be found a change which for township 140, may amount to 25″, according to the month and the sidereal time chosen. Taken over a whole year this change may be anything up to 80″ for township 0, or up to 110″ for township 140, according to the sidereal time considered. Hence if the Field Tables were made out taking a mean position of Polaris for a year, they would be subject to a maximum error of half this amount, that is about 40″ at township 0, and about 55″ at township 140. It will be observed from the diagram that the star crosses its path again and again, occupying approximately the same positions during certain periods of consecutive years. Because of this peculiarity two sets of star tables were previously issued each year, one set for January, February and March of one year, and April, May and June of the next, the other for November and December, September and October, and July and August of three successive years. With this arrangement the maximum error for township 0 is 24″ and for township 140 is 32″. Owing to changes in the path of Polaris the error has been increasing and in order to reduce it as much as possible, periods involving fractional months have been adopted, these being chosen so as to

APPARENT MOTION OF THE POLE STAR

Plate II



The periods covered by each table are outlined in red.

The mean position of the Pole Star adopted for each table is indicated by a small red circle.

give a minimum error for periods covering approximately six months, as shown on Plate II. The mean position of the star for these periods is much less in error than a mean position taken for six consecutive months, and the error of the former tables has by this arrangement been reduced to about 19″ for township 0 and 26″ for township 140. This maximum error is found only on the days at the limits of the tables and at certain hours of those days; at other times the error is negligible.

The periods covered by the tables are outlined in red on Plate II, the mean positions for which the tables are calculated being indicated by small red circles.

COMPUTATION OF THE TABLES OF THE ALTITUDE AND AZIMUTH OF POLARIS.

Azimuth of the Pole Star.— The azimuth is given by:

$$\tan Z = -\frac{\tan P \sec L \sin t}{1-\tan P \tan L \cos t}$$

Z and P are both small quantities. Expanding and expressing Z and P in minutes:

$$Z = -P \sec L \sin t - \tfrac{1}{2} P^2 \sin 1' \sec L \tan L \sin 2t$$
$$-\tfrac{1}{3} P^3 \sin^2 1' \sec L \sin t \{(1+4\tan^2 L)\cos^2 t - \tan^2 L\}$$

The computation of each field table from this formula would be a very laborious undertaking. An auxiliary table is therefore computed for an approximate mean position of the star over several years. For instance, at this date (1916) a right ascension of 1^h30^m and a polar distance of 68′ may be taken. By taking a right ascension for the auxiliary table which ends in 0^m or 5^m, only half as many calculations are required as would otherwise be the case. The argument of the tables is the sidereal time which in the present case is $(t+1^h30^m)$ so that the value of Z computed for $t=0^m$ is tabulated for sidereal time 1^h30^m, that for $t=10^m$ tabulated for 1^h40^m and so on.

For the first term of the formula, $P \sec L$ is a constant factor for each township. It is multiplied by the different values of $\sin t$ from $t=0^h$ to $t=6^h$ and tabulated with the sidereal time as argument. The figures for the other eighteen hours can then be written down.

The second term of the formula is similarly calculated by multiplying the constant $\frac{1}{2} P^2 \sin 1' \sec L \tan L$ for each township, by the different values of $\sin 2t$ from $t=0^h$ to

$t=3^h$. The figures for the remaining twenty-one hours can then be written down. The maximum value of this term is $2'\cdot55$.

Corrections for the third term may be quickly estimated graphically. They are always small, never exceeding $0'\cdot07$.

The term involving P^4 never exceeds but a small fraction of a second and may be neglected.

With attention to the signs of the different terms, the auxiliary table may now be obtained accurately for the assumed position A (Plate II) of the star.

It is now required to obtain from this auxiliary table any required Field Tables, as for instance those covering the periods

October 8 to December 14, 1916,
August 14 to October 6, 1917,
June 2 to August 9, 1918.

The mean position B of the Pole star for these periods is:

$$\text{R.A.} = 1^h\ 31^m\cdot1$$
$$\text{P} = 68'\cdot05$$

The corrections to the auxiliary tables could be found by means of the differential formula for dZ, taking for the present case

$$dt = +1^m\cdot1$$
$$dP = +0'\cdot05$$

Terms of the third order, that is to say, those containing P^2, can be neglected.

It is more convenient, however, to deal with the matter in a different way.

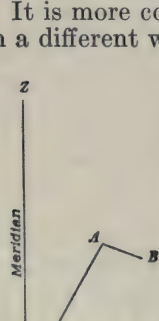


FIG. 5.

Let P, fig. 1, be the pole, Z the zenith, A the mean position of the star for which the auxiliary table has been calculated, and B the position for which the Field Tables are required. Consider an imaginary star at B' so that PB' is always equal and parallel to AB. Then the azimuth of B is approximately equal to the azimuth of A, plus or minus the azimuth of the imaginary star at B'. The approximation is equivalent to disregarding terms of the third order in the calculation by the differential formula, and with an auxiliary table computed every four or five years,

will not amount to more than three or four seconds for the higher latitudes, under the most unfavourable circumstances.

The polar distance of B' $(=AB)$ being very small, its azimuth may be taken as equal to

$$p \sec L \sin t$$

where p is the polar distance and t the hour angle of B'.

The right ascension and polar distance of the star B' may be taken directly off the diagram of the path of Polaris, Plate II. The right ascension is equal to the right ascension of A, plus or minus the angle APB' as the case may be. For the Field Tables considered, the angle is shown on Plate II: its value is $81°\cdot5$ or $5^h\ 26^m$, and the right ascension of the imaginary star B' is

$$1^h\ 30^m + 5^h\ 26^m = 6^h\ 56^m$$

The polar distance, by scaling AB directly from Plate II is found to be $19''\cdot8$ or $0'\cdot33$.

Having obtained the right ascension and polar distance of the imaginary star B', the required corrections $p \sec L \sin t$ can be obtained for each twentieth township by a simple graphical process, tabulated for every 10^m of sidereal time, and applied to the figures of the auxiliary table.

Altitude of the Pole Star.—The correction to be applied to the latitude to obtain the altitude is given by

$$h - L = P \cos t - \tfrac{1}{2} P^2 \sin 1' \tan L \sin^2 t$$

terms involving higher powers of P than the second being inappreciable.

This expression being a function of the latitude, a separate computation would be required for each twentieth township if great accuracy were required, but considering that the term which contains L is small, and moreover that this part of the Field Tables is intended merely to set the telescope for finding the star, it is sufficiently accurate to use a mean value for the latitude (L_m) and to calculate a single table for all townships.

The first term $P \cos t$ has already been tabulated for the azimuth table under the form $P \sin t$. The second term which does not exceed $1'\cdot23$, may be written in the form

$$\tfrac{1}{4} P^2 \sin 1' \tan L_m (1 - \cos 2t)$$

and obtained by a simple graphic process.

As with the azimuth tables, this table is computed for a mean position A of the star over several years.

A small correction equal to $p \cos t$ is necessary to this auxiliary table, for each set of Field Tables issued.

TABLES.

Log. to be added to give log N etc. in ft.
= 7·1339690'7.

TABLE I.

Radii of Curvature of Meridians and Parallels, etc.

Latitude.		log $N \sin 1''$.	log $P \sin 1''$.	log $R \sin 1''$.	Chains in 1″.		Seconds in one Chain.		English Miles in one Degree.	
					Latitude.	Longitude.	Latitude.	Longitude.	Latitude.	Longitude.
°	′						″	″		
42	00	0·1873775	0·0584510	0·1857461	1·5337	1·1441	0·6520	0·8741	69·02	51·48
	10	3818	73144	7589	38	1·1411	20	0·8764	·02	51·35
	20	3860	61711	7717	38	1·1381	20	0·8787	·02	51·21
	30	3903	50212	7845	39	1·1351	20	0·8810	·02	51·08
	40	3946	38645	7973	39	1·1320	19	0·8834	·03	50·94
	50	3989	27010	8101	39	1·1290	19	0·8857	·03	50·81
43	00	4031	15306	8230	40	1·1260	19	0·8881	·03	50·67
	10	4074	0·0503534	8358	40	1·1229	19	0·8905	·03	50·53
	20	4117	0·0491693	8487	41	1·1199	19	0·8930	·03	50·39
	30	4160	79782	8615	41	1·1168	18	0·8954	·04	50·26
	40	4203	67802	8744	42	1·1137	18	0·8979	·04	50·12
	50	4245	55750	8872	42	1·1106	18	0·9004	·04	49·98
44	00	4288	43629	9001	43	1·1075	18	0·9029	·04	49·84
	10	4331	31437	9129	43	1·1044	18	0·9054	·04	49·70
	20	4374	19173	9258	44	1·1013	17	0·9080	·05	49·56
	30	4417	0·0406838	9387	44	1·0982	17	0·9106	·05	49·42
	40	4460	0·0394430	9515	44	1·0951	17	0·9132	·05	49·28
	50	4503	81949	9644	45	1·0919	17	0·9158	·05	49·14

45	00	4546	69396	9773	45	1·0888	17	0·9185	·05	49·00
	10	4589	56769	0·1859901	46	1·0856	16	0·9211	·06	48·85
	20	4631	44067	0·1860030	46	1·0824	16	0·9238	·06	48·71
	30	4674	31292	0159	47	1·0793	16	0·9266	·06	48·57
	40	4717	18442	0288	47	1·0761	16	0·9293	·06	48·42
	50	4760	0·0305517	0416	48	1·0729	16	0·9321	·06	48·28
46	00	4803	0·0292516	0545	48	1·0697	15	0·9349	·07	48·14
	10	4846	79439	0673	49	1·0665	15	0·9377	·07	47·99
	20	4889	66285	0802	49	1·0632	15	0·9405	·07	47·85
	30	4932	53054	0931	49	1·0600	15	0·9434	·07	47·70
	40	4974	39745	1059	50	1·0568	15	0·9463	·07	47·55
	50	5017	26358	1188	50	1·0535	15	0·9492	·08	47·41
47	00	5060	0·0212893	1316	51	1·0502	14	0·9522	·08	47·26
	10	5103	0·0199349	1445	51	1·0470	14	0·9551	·08	47·11
	20	5146	85726	1573	52	1·0437	14	0·9581	·08	46·97
	30	5188	72021	1701	52	1·0404	14	0·9612	·08	46·82
	40	5231	58237	1829	53	1·0371	14	0·9642	·09	46·67
	50	5274	44372	1957	53	1·0338	13	0·9673	·09	46·52
48	00	5317	30425	2086	54	1·0305	13	0·9704	·09	46·37
	10	5359	16396	2214	54	1·0272	13	0·9736	·09	46·22
	20	5402	0·0102285	2341	54	1·0238	13	0·9767	·09	46·07
	30	5445	0·0088090	2469	55	1·0205	13	0·9799	·10	45·92
	40	5487	73812	2597	55	1·0171	12	0·9831	·10	45·77
	50	0·1875530	0·0059449	0·1862725	1·5356	1·0138	0·6512	0·9864	69·10	45·62

TABLE I.—*Continued.*

Radii of Curvature of Meridians and Parallels, etc.

Latitude.		log N sin 1″.	log P sin 1″.	log R sin 1″.	Chains in 1″.		Seconds in one Chain.		English Miles in one Degree.	
					Latitude.	Longitude.	Latitude.	Longitude.	Latitude.	Longitude.
°	′						″	″		
49	00	0·1875572	0·0045001	0·1862852	1·5356	1·0104	0·6512	0·9897	69·10	45·47
	10	5615	30469	2980	57	1·0070	12	0·9930	·11	45·32
	20	5657	15849	3107	57	1·0037	12	0·9964	·11	45·16
	30	5699	0·0001143	3234	58	1·0003	11	0·9997	·11	45·01
	40	5742	9·9986351	3361	58	0·9969	11	1·0031	·11	44·86
	50	5784	71470	3488	58	0·9935	11	1·0066	·11	44·71
50	00	5826	56501	3615	59	0·9900	11	1·0101	·12	44·55
	10	5869	41444	3742	59	0·9866	11	1·0136	·12	44·40
	20	5911	26296	3869	60	0·9832	10	1·0171	·12	44·24
	30	5953	9·9911058	3995	60	0·9797	10	1·0207	·12	44·09
	40	5995	9·9895730	4122	61	0·9763	10	1·0243	·12	43·93
	50	6037	80309	4248	61	0·9728	10	1·0279	·13	43·78
51	00	6079	64797	4374	62	0·9693	10	1·0316	·13	43·62
	10	6121	49192	4500	62	0·9659	10	1·0353	·13	43·46
	20	6163	33493	4625	63	0·9624	09	1·0391	·13	43·31
	30	6205	17701	4751	63	0·9589	09	1·0429	·13	43·15
	40	6247	9·9801813	4876	63	0·9554	09	1·0467	·14	42·99
	50	6289	9·9785830	5002	64	0·9519	09	1·0506	·14	42·83

52	00	6330	69750	5127	64	0·9484	09	1·0544	·14	42·68
	10	6372	53574	5252	65	0·9448	08	1·0584	·14	42·52
	20	6413	37299	5376	65	0·9413	08	1·0624	·14	42·36
	30	6455	20926	5501	66	0·9378	08	1·0664	·15	42·20
	40	6496	9·9704454	5625	66	0·9342	08	1·0704	·15	42·04
	50	6538	9·9687882	5749	66	0·9307	08	1·0745	·15	41·88
53	00	6579	71209	5873	67	0·9271	07	1·0786	·15	41·72
	10	6620	54435	5997	67	0·9235	07	1·0828	·15	41·56
	20	6662	37559	6120	68	0·9199	07	1·0870	·16	41·40
	30	6703	20579	6244	68	0·9163	07	1·0913	·16	41·24
	40	6744	9·9603495	6367	69	0·9127	07	1·0956	·16	41·07
	50	6785	9·9586307	6490	69	0·9091	07	1·0999	·16	40·91
54	00	6826	69012	6612	70	0·9055	06	1·1043	·16	40·75
	10	6866	51612	6735	70	0·9019	06	1·1088	·16	40·59
	20	6907	34104	6857	70	0·8983	06	1·1132	·17	40·42
	30	6948	9·9516488	6979	71	0·8946	06	1·1178	·17	40·26
	40	6988	9·9498763	7101	71	0·8910	06	1·1223	·17	40·09
	50	7029	80928	7222	72	0·8873	05	1·1270	·17	39·93
55	00	7069	62982	7343	72	0·8837	05	1·1316	·17	39·77
	10	7109	44924	7464	73	0·8800	05	1·1363	·18	39·60
	20	7150	26754	7585	73	0·8763	05	1·1411	·18	39·44
	30	7190	9·9408470	7705	73	0·8727	05	1·1459	·18	39·27
	40	7230	9·9390072	7826	74	0·8690	05	1·1508	·18	39·10
	50	0·187270	71557	0·1867945	1·5374	0·8653	0·6504	1·1557	69·18	38·94

TABLE I.—*Continued.*

Radii of Curvature of Meridians and Parallels, etc.

Latitude.		log $N \sin 1''$.	log $P \sin 1''$.	log $R \sin 1''$.	Chains in 1″.		Seconds in one Chain.		English Miles in one Degree.	
					Latitude.	Longitude.	Latitude.	Longitude.	Latitude.	Longitude.
°	′						″	″		
56	00	0·1877310	9·9352927	0·1868065	1·5375	0·8616	0·6504	1·1607	69·19	38·77
	10	7350	34177	8184	75	0·8579	04	1·1657	·19	38·60
	20	7389	9·9315310	8304	76	0·8541	04	1·1708	·19	38·44
	30	7429	9·9296324	8422	76	0·8504	04	1·1759	·19	38·27
	40	7468	77216	8541	76	0·8467	03	1·1811	·19	38·10
	50	7508	57987	8659	77	0·8429	03	1·1863	·20	37·93
57	00	7547	38635	8777	77	0·8392	03	1·1916	·20	37·76
	10	7586	9·9219158	8894	78	0·8354	03	1·1970	·20	37·59
	20	7625	9·9199557	9012	78	0·8317	03	1·2024	·20	37·43
	30	7664	79829	9129	78	0·8279	03	1·2079	·20	37·26
	40	7703	59974	9245	79	0·8241	02	1·2134	·20	37·09
	50	7742	39991	9361	79	0·8203	02	1·2190	·21	36·92
58	00	7781	9·9119877	9478	80	0·8166	02	1·2247	·21	36·75
	10	7819	9·9099633	9593	80	0·8128	02	1·2304	·21	36·57
	20	7858	79257	9709	81	0·8090	02	1·2362	·21	36·40
	30	7896	58747	9824	81	0·8051	02	1·2420	·21	36·23
	40	7934	38102	0·1869938	81	0·8013	01	1·2479	·22	36·06
	50	7972	9·9017321	0·1870053	82	0·7975	01	1·2539	·22	35·89

59	00	8010	9·8996403	0167	82	0·7937	01	1·2600	·22	35·72
	10	8048	75347	0280	83	0·7898	01	1·2661	·22	35·54
	20	8086	54150	0393	83	0·7860	01	1·2723	·22	35·37
	30	8124	32812	0506	83	0·7821	01	1·2786	·23	35·20
	40	8161	9·8911331	0619	84	0·7783	00	1·2849	·23	35·02
	50	8198	9·8889706	0731	84	0·7744	00	1·2913	·23	34·85
60	00	8236	67936	0843	85	0·7705	00	1·2978	·23	34·67
	10	8273	46018	0955	85	0·7667	00	1·3044	·23	34·50
	20	8310	23952	1066	85	0·7628	00	1·3110	·23	34·32
	30	8347	9·8801735	1176	86	0·7589	0·6500	1·3177	·24	34·15
	40	8384	9·8779367	1287	86	0·7550	0·6499	1·3245	·24	33·97
	50	8420	56845	1397	86	0·7511	99	1·3314	·24	33·80
61	00	8457	34169	1506	87	0·7472	99	1·3384	·24	33·62
	10	8493	9·8711336	1615	87	0·7432	99	1·3454	·24	33·45
	20	8529	9·8688345	1724	88	0·7393	99	1·3526	·24	33·27
	30	8565	65194	1832	88	0·7354	99	1·3598	·25	33·09
	40	8601	41882	1940	88	0·7315	98	1·3671	·25	32·92
	50	8637	9·8618406	2048	89	0·7275	98	1·3745	·25	32·74
62	00	8673	9·8594766	2155	89	0·7236	98	1·3820	·25	32·56
	10	8709	70959	2262	90	0·7196	98	1·3896	·25	32·38
	20	8744	46982	2368	90	0·7156	98	1·3973	·25	32·20
	30	8779	9·8522835	2474	90	0·7117	98	1·4051	·26	32·03
	40	8814	9·8498516	2579	91	0·7077	97	1·4130	·26	31·85
	50	0·1878849	74022	0·1872684	1·5391	0·7037	0·6497	1·4210	69·26	31·67

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TABLE I.—*Concluded.*

Radii of Curvature of Meridians and Parallels, etc.

Latitude.		log N sin 1″.	log P sin 1″.	log R sin 1″.	Chains in 1″.		Seconds in one Chain.		English Miles in one Degree.	
					Latitude.	Longitude	Latitude.	Longitude.	Latitude.	Longitude.
°	′						″	″		
63	00	0·1878884	9·8449352	0·1872789	1·5391	0·6997	0·6497	1·4291	69·26	31·49
	10	8919	9·8424503	2893	92	0·6957	97	1·4373	·26	31·31
	20	8954	9·8399475	2996	92	0·6917	97	1·4456	·26	31·13
	30	8988	74262	3100	93	0·6877	97	1·4540	·27	30·95
	40	9022	48866	3202	93	0·6837	97	1·4626	·27	30·77
	50	9056	9·8323282	3305	93	0·6797	96	1·4712	·27	30·59
64	00	9090	9·8297510	3407	94	0·6757	96	1·4800	·27	30·41
	10	9124	71546	3508	94	0·6717	96	1·4888	·27	30·23
	20	9158	45389	3609	94	0·6676	96	1·4978	·27	30·04
	30	9191	9·8219035	3709	95	0·6636	96	1·5069	·28	29·86
	40	9225	9·8192482	3809	95	0·6596	96	1·5162	·28	29·68
	50	9258	65730	3909	95	0·6555	95	1·5256	·28	29·50
65	00	9291	38774	4008	96	0·6514	95	1·5351	·28	29·32
	10	9324	9·8111610	4107	96	0·6474	95	1·5447	·28	29·13
	20	9356	9·8084240	4205	96	0·6433	95	1·5544	·28	28·95
	30	9389	56659	4302	97	0·6392	95	1·5644	·29	28·77
	40	9421	28862	4399	97	0·6352	95	1·5744	·29	28·58
	50	9453	9·8000850	4496	97	0·6311	95	1·5846	·29	28·40

66	00	9485	9·7972618	4592	98	0·6270	94	1·5949	·29	28·21
	10	9517	44164	4688	98	0·6229	94	1·6054	·29	28·03
	20	9549	9·7915485	4783	98	0·6188	94	1·6160	·29	27·85
	30	9580	9·7886577	4877	99	0·6147	94	1·6268	·29	27·66
	40	9612	57439	4971	99	0·6106	94	1·6378	·30	27·48
	50	9643	9·7828065	5065	1·5399	0·6065	94	1·6489	·30	27·29
67	00	9674	9·7798454	5158	1·5400	0·6023	94	1·6602	·30	27·11
	10	9705	68602	5251	00	0·5982	93	1·6716	·30	26·92
	20	9736	38506	5343	00	0·5941	93	1·6833	·30	26·73
	30	9766	9·7708163	5434	01	0·5900	93	1·6951	·30	26·55
	40	9796	9·7677568	5525	01	0·5858	93	1·7070	·31	26·36
	50	9827	46718	5615	01	0·5817	93	1·7192	·31	26·17
68	00	9857	9·7615610	5705	02	0·5775	93	1·7316	·31	25·99
	10	9886	9·7584241	5795	02	0·5734	93	1·7441	·31	25·80
	20	9916	52605	5883	02	0·5692	92	1·7569	·31	25·61
	30	9945	9·7520699	5972	03	0·5650	92	1·7698	·31	25·43
	40	0·1879975	9·7488520	6059	03	0·5609	92	1·7830	·31	25·24
	50	0·1880004	56064	6147	03	0·5567	92	1·7964	·31	25·05
69	00	0032	9·7423324	6233	04	0·5525	92	1·8100	·32	24·86
	10	0061	9·7390298	6319	04	0·5483	92	1·8238	·32	24·67
	20	0090	56983	6405	04	0·5441	92	1·8378	·32	24·49
	30	0118	9·7323371	6490	05	0·5399	92	1·8521	·32	24·30
	40	0146	9·7289460	6574	05	0·5357	91	1·8666	·32	24·11
	50	0174	55244	6658	05	0·5315	91	1·8814	·32	23·92
70	00	0·1880202	9·7220719	0·1876741	1·5405	0·5273	0·6491	1·8964	69·32	23·73

TABLE II.

Corrections to be applied to the Logarithms of $R \sin 1''$ and $N \sin 1''$ in Table I, for Clarke's later values of the Dimensions of the Earth.

Latitude.	$d(\log R \sin 1'')$.	$d(\log N \sin 1'')$.	Latitude.	$d(\log R \sin 1'')$.	$d(\log N \sin 1'')$.
°			°		
42.....	−0·0000021	+0·0000063	56.....	+0·0000034	+0·0000081
43.....	17	64	57.....	37	82
44.....	13	66	58.....	41	84
45.....	09	67	59.....	45	85
46.....	05	68	60.....	48	86
47.....	−0·0000001	70	61.....	51	87
48.....	+0·0000003	71	62.....	55	88
49.....	07	72	63.....	58	89
50.....	11	74	64.....	61	90
51.....	15	75	65.....	64	91
52.....	19	76	66.....	67	92
53.....	23	77	67.....	70	93
54.....	26	79	68.....	73	94
55.....	30	80	69.....	76	95
			70.....	78	96

TABLE III.

Latitudes, etc., of Base and Correction Lines. First and Second Systems of Survey.

No. of Township.	Number of Line.	Latitude.			Log $N \sin 1''$.	Log $P \sin 1''$.	Log $R \sin 1''$.	Longitude covered by 489 chains of westing.	
		°	′	″				′	″
0	1st Base	49	00	00·00	0·1875572	0·0045001	0·1862852	8	03·959
2	1st Correction		10	36·86	5618	0·0029573	2988		05·681
4	2nd Base		21	13·71	5662	0·0014047	3123		07·421
6	2nd Correction		31	50·53	5707	9·9998425	3258		09·177
8	3rd Base		42	27·34	5752	9·9982704	3393		10·951
10	3rd Correction		53	04·12	5797	9·9966886	3527		12·743
12	4th Base	50	03	40·89	5842	9·9950968	3662		14·552
14	4th Correction		14	17·63	5887	9·9934951	3797		16·379
16	5th Base		24	54·36	5932	9·9918832	3931		18·225
18	5th Correction		35	31·07	5976	9·9902611	4065		20·089
20	6th Base		46	07·75	6021	9·9886289	4199		21·972
22	6th Correction		56	44·42	6065	9·9869863	4333		23·875
24	7th Base	51	07	21·07	6110	9·9853334	4466		25·796
26	7th Correction		17	57·69	6154	9·9836701	4600		27·737
28	8th Base		28	34·30	6199	9·9819962	4733		29·698
30	8th Correction		39	10·89	6244	9·9803117	4866		31·678
32	9th Base		49	47·46	6288	9·9786165	4999		33·680
34	9th Correction	52	00	24·01	6332	9·9769105	5132		35·701
36	10th Base		11	00·54	6376	9·9751935	5264		37·744
38	10th Correction		21	37·05	6420	9·9734658	5396		39·808
40	11th Base		32	13·54	6464	9·9717268	5529		41·894
42	11th Correction		42	50·02	6508	9·9699768	5660		44·001
44	12th Base		53	26·47	6552	9·9682156	5792		46·130
46	12th Correction	53	04	02·90	6596	9·9664431	5923		48·282
48	13th Base		14	39·32	0·1876640	9·9646592	0·1866055	8	50·456

TABLE IV.

Latitudes, etc., of Base and Correction Lines. Third System of Survey.

No. of Township.	Number of Line.	Latitude.			Log N sin 1″.	Log P sin 1″.	Log R sin 1″.	Longitude covered by 486 chains of westing.	
		°	′	″				′	″
0	1st Base	49	00	00·00	0·1875572	0·0045001	0·1862852	8	00·990
2	1st Correction		10	29·05	5617	0·0029763	2986		02·681
4	2nd Base		20	58·08	5661	0·0014430	3119		04·388
6	2nd Correction		31	27·09	5706	9·9999002	3253		06·112
8	3rd Base		41	56·08	5750	9·9983479	3386		07·852
10	3rd Correction		52	25·06	5795	9·9967860	3519		09·610
12	4th Base	50	02	54·01	5839	9·9952144	3652		11·385
14	4th Correction		13	22·95	5883	9·9936331	3785		13·178
16	5th Base		23	51·86	5927	9·9920419	3918		14·988
18	5th Correction		34	20·76	5971	9·9904408	4050		16·816
20	6th Base		44	49·63	6016	9·9888298	4182		18·662
22	6th Correction		55	18·49	6060	9·9872087	4315		20·527
24	7th Base	51	05	47·33	6104	9·9855775	4447		22·411
26	7th Correction		16	16·15	6148	9·9839362	4578		24·313
28	8th Base		26	44·95	6192	9·9822845	4710		26·235
30	8th Correction		37	13·73	6235	9·9806225	4842		28·176
32	9th Base		47	42·49	6279	9·9789501	4973		30·136
34	9th Correction		58	11·24	6323	9·9772672	5104		32·117
36	10th Base	52	08	39·96	6366	9·9755738	5235		34·118
38	10th Correction		19	08·66	6410	9·9738696	5366		36·139

40	11th Base.....		29	37·35	6454	9·9721546	5496		38·181
42	11th Correction.....		40	06·02	6497	9·9704288	5626		40·245
44	12th Base.....		50	34·67	6540	9·9686921	5756		42·329
46	12th Correction.....	53	01	03·30	6584	9·9669444	5886		44·435
48	13th Base.....		11	31·91	6627	9·9651856	6016		46·563
50	13th Correction.....		22	00·50	6670	9·9634157	6145		48·714
52	14th Base.....		32	29·07	6713	9·9616344	6274		50·887
54	14th Correction.....		42	57·63	6756	9·9598417	6403		53·083
56	15th Base.....		53	26·17	6799	9·9580376	6532		55·302
58	15th Correction.....	54	03	54·68	6842	9·9562219	6660		57·545
60	16th Base.....		14	23·18	6884	9·9543946	6788	8	59·811
62	16th Correction.....		24	51·66	6927	9·9525555	6916	9	02·102
64	17th Base.....		35	20·12	6969	9·9507045	7044		04·417
66	17th Correction.....		45	48·57	7012	9·9488415	7171		06·758
68	18th Base.....		56	16·99	7054	9·9469665	7298		09·123
70	18th Correction.....	55	06	45·40	7097	9·9450793	7425		11·515
72	19th Base.....		17	13·79	7139	9·9431799	7552		13·932
74	19th Correction.....		27	42·16	7181	9·9412681	7678		16·376
76	20th Base.....		38	10·51	7223	9·9393438	7804		18·847
78	20th Correction.....		48	38·85	7265	9·9374068	7929		21·345
80	21st Base.....		59	07·16	7306	9·9354571	8055		23·870
82	21st Correction.....	56	09	35·46	7348	9·9334947	8180		26·424
84	22nd Base.....		20	03·74	7389	9·9315193	8304		29·006
86	22nd Correction.....		30	32·00	7431	9·9295308	8429		31·618
88	23rd Base.....	56	41	00·24	0·1877472	9·9275292	0·1868553	9	34·258

TABLE IV—*Concluded.*

Latitudes, etc., of Base and Correction Lines. Third System of Survey.

No. of Township.	Number of Line.	Latitude.			Log N sin 1″.	Log P sin 1″.	Log R sin 1″.	Longitude covered by 486 chains of westing.	
		°	′	″				′	″
90	23rd Correction	56	51	28·47	0·1877514	9·9255142	0·1868676	9	36·929
92	24th Base	57	01	56·68	7555	9·9234857	8800		39·630
94	24th Correction		12	24·87	7596	9·9214437	8923		42·362
96	25th Base		22	53·04	7637	9·9193880	9045		45·125
98	25th Correction		33	21·19	7677	9·9173186	9168		47·919
100	26th Base		43	49·33	7718	9·9152352	9290		50·747
102	26th Correction		54	17·45	7759	9·9131377	9411		53·607
104	27th Base	58	04	45·55	7799	9·9110260	9533		56·500
106	27th Correction		15	13·63	7839	9·9088999	9654	9	59·427
108	28th Base		25	41·70	7879	9·9067593	9774	10	02·389
110	28th Correction		36	09·75	7920	9·9046041	0·1869894		05·386
112	29th Base		46	37·78	7960	9·9024341	0·1870014		08·418
114	29th Correction		57	05·80	7999	9·9002491	0134		11·487
116	30th Base	59	07	33·79	8039	9·8980491	0253		14·592
118	30th Correction		18	01·77	8079	9·8958338	0371		17·735
120	31st Base		28	29·74	8118	9·8936032	0489		20·916
122	31st Correction		38	57·68	8157	9·8913570	0607		24·136
124	32nd Base		49	25·61	8196	9·8890950	0725		27·395
126	32nd Correction		59	53·52	8235	9·8868172	0842		30·695
128	33rd Base	60	10	21·42	8274	9·8845233	0959		34·035

130	33rd Correction.....		20	49·30	8313	9·8822132	1075		37·416
132	34th Base.....		31	17·16	8352	9·8798867	1191		40·840
134	34th Correction.....		41	45·00	8390	9·8775437	1306		44·307
136	35th Base.....		52	12·83	8429	9·8751839	1421		47·817
138	35th Correction.....	61	02	40·64	8467	9·8728072	1535		51·372
140	36th Base.....		13	08·44	8505	9·8704133	1649		54·973
142	36th Correction.....		23	36·22	8542	9·8680021	1763	10	58·619
144	37th Base.....	61	34	03·98	0·1878580	9·8655735	0·1871876	11	02·312

TABLE V.

Chord Azimuths, Deflections, Deflection Offsets, etc., for Base Lines. First and Second Systems of Survey.

No. of Base Line.	Chord Azimuth Sexagesimal.	Chord Azimuth Decimal.	Deflection Sexagesimal.	Deflection Decimal.	Deflection Offset for one Chain Distance.	Longitude covered by one Range.	No. of Township.
	° ′ ″	°	′ ″	°	inches.	s.	
1	89 56 57·4	89·9493	6 05·2	0·1014	1·402	32·3	0
2	55·1	·9486	09·8	·1027	1·420	32·5	4
3	52·8	·9480	14·5	·1040	1·438	32·7	8
4	50·4	·9473	19·2	·1053	1·456	33·0	12
5	48·0	·9467	24·0	·1067	1·474	33·2	16
6	45·6	·9460	28·8	·1080	1·493	33·5	20
7	43·1	·9453	33·8	·1094	1·512	33·7	24
8	40·6	·9446	38·8	·1108	1·531	34·0	28
9	38·1	·9439	43·8	·1122	1·551	34·2	32
10	35·5	·9432	49·0	·1136	1·570	34·5	36
11	32·9	·9425	54·3	·1151	1·591	34·8	40
12	30·2	·9417	6 59·6	·1165	1·611	35·1	44
13	27·5	·9410	7 05·0	·1180	1·632	35·4	48

TABLE VI.

Chord Azimuths, Deflections, Deflection Offsets, etc., for Base Lines. Third System of Survey.

No. of Base Line.	Chord Azimuth Sexagesimal.	Chord Azimuth Decimal.	Deflection Sexagesimal.	Deflection Decimal.	Deflection Offset for one Chain Distance.	Longitude covered by one Range.	No. of Township.
	° ′ ″	°	′ ″	°	inches.	s.	
1	89 56 58·5	89·9496	6 03·0	0·1008	1·394	32·1	0
2	56·3	·9490	07·5	·1021	1·411	32·3	4
3	54·0	·9483	12·1	·1033	1·429	32·5	8
4	51·7	·9477	16·7	·1046	1·446	32·8	12
5	49·4	·9470	21·4	·1059	1·464	33·0	16
6	46·9	·9464	26·1	·1073	1·483	33·2	20
7	44·5	·9457	31·0	·1086	1·501	33·5	24
8	42·1	·9450	35·9	·1100	1·520	33·7	28
9	39·6	·9443	40·9	·1114	1·539	34·0	32
10	37·0	·9436	45·9	·1128	1·559	34·3	36
11	34·5	·9429	51·1	·1142	1·578	34·5	40
12	31·9	·9422	56·3	·1156	1·598	34·8	44
13	29·2	·9414	7 01·6	·1171	1·619	35·1	48
14	26·5	·9407	07·0	·1186	1·639	35·4	52
15	23·8	·9399	12·5	·1201	1·661	35·7	56
16	21·0	·9392	18·0	·1217	1·682	36·0	60
17	18·2	·9384	23·7	·1233	1·704	36·3	64
18	15·3	·9376	29·5	·1249	1·726	36·6	68
19	12·3	·9368	35·3	·1265	1·748	36·9	72
20	09·4	·9359	41·3	·1281	1·771	37·3	76
21	06·3	·9351	47·4	·1298	1·795	37·6	80
22	03·2	·9342	53·6	·1316	1·818	37·9	84
23	00·1	·9334	59·9	·1333	1·843	38·3	88
24	89 55 56·9	·9325	8 06·3	·1351	1·867	38·6	92
25	53·6	·9316	12·8	·1369	1·892	39·0	96
26	50·3	·9306	19·5	·1387	1·918	39·4	100
27	46·8	·9297	26·3	·1406	1·944	39·8	104
28	43·4	·9287	33·2	·1426	1·971	40·2	108
29	39·9	·9277	40·3	·1445	1·998	40·6	112
30	36·2	·9267	47·5	·1465	2·025	41·0	116
31	32·6	·9257	54·9	·1486	2·054	41·4	120
32	28·8	·9247	9 02·4	·1507	2·083	41·8	124
33	25·0	·9236	10·0	·1528	2·112	42·3	128
34	21·1	·9225	17·9	·1550	2·142	42·7	132
35	17·1	·9214	25·9	·1572	2·173	43·2	136
36	13·0	·9203	34·1	·1595	2·204	43·7	140
37	08·8	·9191	42·4	·1618	2·236	44·2	144

TABLE VII.

Chord Azimuths, Deflections, Deflection Offsets, Jogs, etc., for Correction Lines.
First and Second Systems of Survey.

No. of Correction Line.	Chord Azimuth Sexagesimal.	Chord Azimuth Decimal.	Deflection Sexagesimal.	Deflection Decimal.	Deflection Offset for one chain distance.	Length of one Range on Correction Line.		Jog.	Convergence or Divergence on Half Section.	No. of Township.
						North side of Road.	South side of Road.			
	° ′ ″	°	′ ″	°	inches	chains	chains	chains	links	
1	89 56 56·9	89·9491	6 06·2	0·1017	1·406	490·751	487·266	3·485	14·5	2
2	54·6	·9485	10·8	·1030	1·424	·773	·244	·529	14·7	6
3	52·3	·9479	15·5	·1043	1·442	·796	·222	·574	14·9	10
4	49·9	·9472	20·2	·1056	1·460	·818	·200	·618	15·1	14
5	47·5	·9465	25·0	·1069	1·478	·841	·177	·664	15·3	18
6	45·1	·9459	29·8	·1083	1·497	·865	·154	·711	15·5	22
7	42·7	·9452	34·7	·1096	1·516	·888	·131	·758	15·7	26
8	40·2	·9445	39·7	·1110	1·535	·913	·107	·806	15·9	30
9	37·6	·9438	44·8	·1124	1·554	·937	·083	·854	16·1	34
10	35·0	·9430	50·0	·1139	1·574	·962	·058	·904	16·3	38
11	32·4	·9423	6 55·2	·1153	1·594	490·987	·034	3·953	16·5	42
12	89 56 29·7	89·9416	7 00·6	0·1168	1·615	491·012	487·008	4·004	16·7	46

TABLE VIII.

Chord Azimuths, Deflections, Deflection Offsets, Jogs, etc., for Correction Lines. Third System of Survey.

No. of Correction Line.	Chord Azimuth Sexagesimal.	Chord Azimuth Decimal.	Deflection Sexagesimal.	Deflection Decimal.	Deflection Offset for one chain distance.	Length of one Range on Correction Line.		Jog.	Convergence or Divergence on Half Section	No. of Township.
						North side of Road.	South side of Road.			
	▫ ′ ″	°	′ ″	°	inches	chains	chains	chains	links	
1	89 56 58·0	89·9494	6 04·0	0·1011	1·398	487·719	484·298	3·421	14·3	2
2	55·7	·9488	08·5	·1024	1·415	·740	·277	·463	14·4	6
3	53·5	·9482	13·0	·1036	1·432	·762	·255	·507	14·6	10
4	51·2	·9475	17·6	·1049	1·450	·784	·234	·550	14·8	14
5	48·8	·9469	22·3	·1062	1·468	·806	·212	·594	15·0	18
6	46·4	·9462	27·1	·1075	1·486	·829	·189	·640	15·2	22
7	44·0	·9456	31·9	·1089	1·505	·852	·167	·685	15·4	26
8	41·6	·9449	36·8	·1102	1·524	·875	·144	·731	15·5	30
9	39·1	·9442	41·8	·1116	1·543	·899	·120	·779	15·7	34
10	36·5	·9435	46·9	·1130	1·562	·923	·097	·826	15·9	38
11	34·0	·9428	52·0	·1144	1·582	·947	·072	·875	16·1	42
12	31·4	·9420	57·2	·1159	1·602	·972	·048	·924	16·4	46
13	28·7	·9413	7 02·6	·1174	1·622	487·997	484·023	3·974	16·6	50
14	26·0	·9406	07·9	·1189	1·643	488·023	483·998	4·025	16·8	54
15	23·3	·9398	13·4	·1204	1·664	·049	·972	·077	17·0	58
16	20·5	·9390	19·0	·1219	1·686	·076	·946	·130	17·2	62
17	17·7	·9382	24·7	·1235	1·707	·103	·920	·183	17·4	66
18	14·8	·9374	30·4	·1251	1·729	·130	·893	·237	17·7	70
19	11·8	·9366	36·3	·1267	1·752	·158	·865	·293	17·9	74
20	89 56 08·9	89·9358	7 42·3	0·1284	1·775	488·187	483·837	4·350	18·1	78

TABLE VIII.—*Concluded.*

Chord Azimuths, Deflections, Deflection Offsets, Jogs, etc., for Correction Lines. Third System of Survey.

No. of Correction Line.	Chord Azimuth Sexagesimal.	Chord Azimuth Decimal.	Deflection Sexagesimal.	Deflection Decimal.	Deflection Offset for one chain distance.	Length of one Range on Correction Line.		Jog.	Convergence or Divergence on Half Section	No. of Township.
						North side of Road.	South side of Road.			
	° ′ ″	°	′ ″	°	inches	chains	chains	chains	links	
21	89 56 05·8	89·9349	7 48·3	0·1301	1·798	488·216	483·809	4·407	18·4	82
22	02·7	·9341	54·5	·1318	1·822	·245	·780	·465	18·6	86
23	89 55 59·6	·9332	8 00·8	·1336	1·846	·275	·750	·525	18·9	90
24	56·4	·9323	07·3	·1354	1·871	·306	·720	·586	19·1	94
25	53·1	·9314	13·8	·1372	1·896	·337	·690	·647	19·4	98
26	49·8	·9305	20·5	·1390	1·922	·369	·658	·711	19·6	102
27	46·4	·9295	27·3	·1409	1·948	·401	·627	·775	19·9	106
28	42·9	·9286	34·2	·1428	1·974	·434	·594	·840	20·2	110
29	39·4	·9276	41·3	·1448	2·001	·468	·561	·907	20·4	114
30	35·8	·9266	48·5	·1468	2·029	·503	·527	4·976	20·7	118
31	32·1	·9256	55·8	·1488	2·057	·538	·493	5·045	21·0	122
32	28·3	·9245	9 03·3	·1509	2·086	·574	·458	·116	21·3	126
33	24·5	·9235	11·0	·1531	2·116	·610	·422	·188	21·6	130
34	20·6	·9224	18·8	·1552	2·146	·648	·385	·263	21·9	134
35	16·6	·9213	26·8	·1574	2·176	·686	·347	·339	22·2	138
36	89 55 12·5	89·9201	9 35·0	0·1597	2·208	488·726	483·309	5·416	22·6	142

TABLE IX.

Latitude, with Logarithms of Secant and Tangent for the North Boundary of each Section, and the widths of Quarter Sections on such Boundaries.

First and Second Systems of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
	36	49 00 00·00	0·183 06	0·060 84	40·000
1	1	00 53·07	19	0·061 06	39·988
	12	01 46·14	31	29	·976
	13	02 39·22	44	51	·964
	24	03 32·29	57	74	·952
	25	04 25·36	70	97	·940
	36	05 18·43	83	0·062 19	·928
2	1	06 11·51	96	42	·916
	12	07 04·58	0·184 09	64	·904
	13	07 57·65	22	87	·892
	24	08 50·72	35	0·063 09	·880
	25	09 43·79	48	32	·868
	36	10 36·86	60	55	39·856 40·146
3	1	11 29·93	73	77	·134
	12	12 23·01	86	0·064 00	·122
	13	13 16·08	99	22	·109
	24	14 09·15	0·185 12	45	·097
	25	15 02·22	25	68	·085
	36	15 55·29	38	90	·073
4	1	16 48·36	51	0·065 13	·061
	12	17 41·43	64	35	·049
	13	18 34·50	77	58	·036
	24	19 27·57	90	81	·024
	25	20 20·64	0·186 03	0·066 03	·012
	36	21 13·71	16	26	40·000
5	1	22 06·78	29	48	39·988
	12	22 59·85	42	71	·976
	13	23 52·92	55	94	·963
	24	24 45·98	68	0·067 16	·951
	25	25 39·05	81	39	·939
	36	26 32·12	94	61	·927

TABLE IX.—*Continued.*

Latitude, with Logarithms of Secant and Tangent, etc.

First and Second Systems of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
6	1	49 27 25·19	0·187 07	0·067 84	39·915
	12	28 18·26	21	0·068 07	·902
	13	29 11·33	34	29	·890
	24	30 04·40	47	52	·878
	25	30 57·46	60	75	·866
	36	31 50·53	73	97	{39·854 40·148
7	1	32 43·60	86	0·069 20	·135
	12	33 36·67	99	42	·123
	13	34 29·74	0·188 12	65	·111
	24	35 22·80	25	88	·099
	25	36 15·87	38	0·070 10	·086
	36	37 08·94	52	33	·074
8	1	38 02·00	65	56	·062
	12	38 55·07	78	78	·049
	13	39 48·14	91	0·071 01	·037
	24	40 41·20	0·189 04	24	·025
	25	41 34·27	17	46	·012
	36	42 27·34	30	69	40·000
9	1	43 20·40	44	92	39·988
	12	44 13·47	57	0·072 14	·975
	13	45 06·54	70	37	·963
	24	45 59·60	83	60	·951
	25	46 52·67	96	82	·938
	36	47 45·73	0·190 10	0·073 05	·926
10	1	48 38·80	23	28	·914
	12	49 31·86	36	50	·901
	13	50 24·93	49	73	·889
	24	51 17·99	63	96	·877
	25	52 11·06	76	0·074 18	·864
	36	53 04·12	89	41	{39·852 40·150
11	1	53 57·19	0·191 02	64	·137
	12	54 50·25	16	86	·125
	13	55 43·32	29	0·075 09	·112
	24	56 36·38	42	32	·100
	25	57 29·44	55	54	·087
	36	58 22·51	69	77	·075

TABLE IX.—*Continued.*

Latitude, with Logarithms of Secant and Tangent, etc.

First and Second Systems of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
12	1	49 59 15·57	0·191 82	0·076 00	40·062
	12	50 00 08·63	95	22	·050
	13	01 01·70	0·192 09	45	·037
	24	01 54·76	22	68	·025
	25	02 47·82	35	90	·013
	36	03 40·89	49	0·077 13	40·000
13	1	04 33·95	62	36	39·988
	12	05 27·01	75	59	·975
	13	06 20·08	89	81	·963
	24	07 13·14	0·193 02	0·078 04	·950
	25	08 06·20	16	27	·938
	36	08 59·26	29	49	·925
14	1	09 52·32	42	72	·913
	12	10 45·39	56	95	·900
	13	11 38·45	69	0·079 17	·888
	24	12 31·51	83	40	·875
	25	13 24·57	96	63	·863
	36	14 17·63	0·194 09	86	{39·850 {40·152
15	1	15 10·69	23	0·080 08	·139
	12	16 03·76	36	31	·126
	13	16 56·82	50	54	·114
	24	17 49·88	63	77	·101
	25	18 42·94	77	99	·088
	36	19 36·00	90	0·081 22	·076
16	1	20 29·06	0·195 04	45	·063
	12	21 22·12	17	67	·050
	13	22 15·18	31	90	·038
	24	23 08·24	44	0·082 13	·025
	25	24 01·30	57	36	·013
	36	24 54·36	71	58	40·000
17	1	25 47·42	85	81	39·987
	12	26 40·48	98	0·083 04	·975
	13	27 33·54	0·196 12	27	·962
	24	28 26·60	25	49	·949
	25	29 19·66	39	72	·937
	36	30 12·71	52	95	·924

TABLE IX.—*Continued.*

Latitude, with Logarithms of Secant and Tangent, etc.

First and Second Systems of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
18	1	50 31 05·77	0·196 66	0·084 18	39·911
	12	31 58·83	79	41	·899
	13	32 51·89	93	63	·886
	24	33 44·95	0·197 06	86	·873
	25	34 38·01	20	0·085 09	·861
	36	35 31·07	34	32	{39·848 40·153
19	1	36 24·12	47	54	·141
	12	37 17·18	61	77	·128
	13	38 10·24	75	0·086 00	·115
	24	39 03·30	88	23	·102
	25	39 56·35	0·198 02	46	·089
	36	40 49·41	15	68	·077
20	1	41 42·47	29	91	·064
	12	42 35·53	43	0·087 14	·051
	13	43 28·58	56	37	·038
	24	44 21·64	70	59	·026
	25	45 14·70	84	82	·013
	36	46 07·75	97	0·088 05	40·000
21	1	47 00·81	0·199 11	28	39·987
	12	47 53·86	25	51	·974
	13	48 46·92	38	74	·962
	24	49 39·98	52	96	·949
	25	50 33·03	66	0·089 19	·936
	36	51 26·09	80	42	·923
22	1	52 19·14	93	65	·910
	12	53 12·20	0·200 07	88	·897
	13	54 05·25	21	0·090 10	·885
	24	54 58·31	35	33	·872
	25	55 51·36	48	56	·859
	36	56 44·42	62	79	{39·846 40·155
23	1	57 37·47	76	0·091 02	·142
	12	58 30·53	90	25	·130
	13	50 59 23·58	0·201 03	47	·117
	24	51 00 16·64	17	70	·104
	25	01 09·69	31	93	·091
	36	02 02·74	45	0·092 16	·078

TABLE IX.—*Continued.*

Latitude, with Logarithms of Secant and Tangent, etc.

First and Second Systems of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
24	1	51 02 55·80	0·201 59	0·092 39	40·065
	12	03 48·85	72	62	·052
	13	04 41·91	86	84	·039
	24	05 34·96	0·202 00	0·093 07	·026
	25	06 28·01	14	30	·013
	36	07 21·07	28	53	40·000
25	1	08 14·12	42	76	39·987
	12	09 07·17	56	99	·974
	13	10 00·22	69	0·094 22	·961
	24	10 53·28	83	45	·948
	25	11 46·33	97	67	·935
	36	12 39·38	0·203 11	90	·922
26	1	13 32·43	25	0·095 13	·909
	12	14 25·49	39	36	·896
	13	15 18·54	53	59	·883
	24	16 11·59	67	82	·870
	25	17 04·64	81	0·096 05	·857
	36	17 57·70	95	28	39·844 40·157
27	1	18 50·75	0·204 08	50	·144
	12	19 43·80	22	73	·131
	13	20 36·85	36	96	·118
	24	21 29·90	50	0·097 19	·105
	25	22 22·95	64	42	·092
	36	23 16·00	78	65	·079
28	1	24 09·05	92	88	·066
	12	25 02·10	0·205 06	0·098 11	·052
	13	25 55·15	20	34	·039
	24	26 48·20	34	57	·026
	25	27 41·25	48	80	·013
	36	28 34·30	62	0·099 02	40·000
29	1	29 27·35	76	25	39·987
	12	30 20·40	90	48	·974
	13	31 13·45	0·206 04	71	·961
	24	32 06·50	19	94	·947
	25	32 59·55	33	0·100 17	·934
	36	33 52·60	47	40	·921

TABLE IX.—*Continued.*

Latitude, with Logarithms of Secant and Tangent, etc.

First and Second Systems of Survey.

Township.	Section.	Latitude *L.*			Log Sec *L.*	Log Tan *L.*	Quarter Section.
		°	′	″			chains.
30	1	51	34	45·65	0·206 61	0·100 63	39·908
	12		35	38·70	75	86	·895
	13		36	31·75	89	0·101 09	·882
	24		37	24·79	0·207 03	32	·868
	25		38	17·84	17	55	·855
	36	51	39	10·89	0·207 31	0·101 78	39·842
41	36	52	37	31·78	0·216 80	0·116 99	39·918
42	1		38	24·82	94	0·117 22	·904
	12		39	17·86	0·217 09	45	·891
	13		40	10·90	23	69	·877
	24		41	03·94	38	92	·863
	25		41	56·98	53	0·118 15	·850
	36		42	50·02	67	38	{39·836 40·166
43	1		43	43·05	82	61	·152
	12		44	36·09	97	84	·138
	13		45	29·13	0·218 11	0·119 08	·124
	24		46	22·17	26	31	·110
	25		47	15·21	41	54	·097
	36		48	08·24	56	77	·083
44	1		49	01·28	70	0·120 00	·069
	12		49	54·32	85	23	·055
	13		50	47·36	0·219 00	47	·041
	24		51	40·39	14	70	·028
	25		52	33·43	29	93	·014
	36		53	26·47	44	0·121 16	40·000
45	1		54	19·50	59	39	39·986
	12		55	12·54	73	63	·972
	13		56	05·58	88	86	·959
	24		56	58·61	0·220 03	0·122 09	·945
	25		57	51·65	18	32	·931
	36		58	44·69	33	56	·917

TABLE IX.—*Concluded.*

Latitude, with Logarithms of Secant and Tangent, etc.

First and Second Systems of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
46	1	52 59 37·72	0·220 47	0·122 79	39·903
	12	53 00 30·76	62	0·123 02	·889
	13	01 23·79	77	25	·876
	24	02 16·83	92	49	·862
	25	03 09·87	0·221 07	72	·848
	36	04 02·90	22	95	39·834 40·168
47	1	04 55·94	37	0·124 18	·154
	12	05 48·97	51	42	·140
	13	06 42·01	66	65	·126
	24	07 35·04	81	88	·112
	25	08 28·08	96	0·125 11	·098
	36	09 21·11	0·222 11	35	·084
48	1	10 14·15	26	58	·070
	12	11 07·18	41	81	·056
	13	12 00·21	56	0·126 04	·042
	24	12 53·25	71	28	·028
	25	13 46·28	86	51	·014
	36	14 39·32	0·223 00	74	40·000

TABLE X.

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
	36	49 00 00·00	0·183 06	0·060 84	40·000
1	1	00 52·75	19	0·061 06	39·988
	12	01 44·84	31	28	·976
	13	02 37·59	44	51	·965
	24	03 29·69	57	73	·953
	25	04 22·43	69	95	·941
	36	05 14·53	82	0·062 17	·929
2	1	06 07·27	95	40	·917
	12	06 59·37	0·184 08	62	·905
	13	07 52·11	20	85	·894
	24	08 44·21	33	0·063 07	·882
	25	09 36·96	46	29	·870
	36	10 29·05	59	51	{39·858 40·143
3	1	11 21·80	71	74	·131
	12	12 13·89	84	96	·119
	13	13 06·63	97	0·064 18	·107
	24	13 58·73	0·185 10	41	·095
	25	14 51·47	23	63	·084
	36	15 43·57	35	85	·072
4	1	16 36·31	48	0·065 08	·060
	12	17 28·41	61	30	·048
	13	18 21·15	74	52	·036
	24	19 13·24	87	74	·024
	25	20 05·99	0·186 00	97	·012
	36	20 58·08	12	0·066 19	40·000
5	1	21 50·82	25	42	39·988
	12	22 42·92	38	64	·976
	13	23 35·66	51	86	·964
	24	24 27·75	64	0·067 08	·952
	25	25 20·50	77	31	·940
	36	26 12·59	90	53	·928
6	1	27 05·33	0·187 03	76	·916
	12	27 57·42	15	98	·904
	13	28 50·17	28	0·068 20	·892
	24	29 42·26	41	43	·880
	25	30 35·00	54	65	·868
	36	31 27·09	67	87	{39·856 40·145

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
7	1	49 32 19·83	0·187 80	0·069 10	40·133
	12	33 11·92	93	32	·121
	13	34 04·67	0·188 06	54	·109
	24	34 56·76	19	77	·097
	25	35 49·50	32	99	·085
	36	36 41·59	45	0·070 21	·073
8	1	37 34·33	58	44	·060
	12	38 26·42	71	66	·048
	13	39 19·16	84	89	·036
	24	40 11·25	97	0·071 11	·024
	25	41 03·99	0·189 10	33	·012
	36	41 56·08	23	56	40·000
9	1	42 48·82	36	78	39·988
	12	43 40·91	49	0·072 00	·976
	13	44 33·65	62	23	·964
	24	45 25·74	75	45	·951
	25	46 18·48	88	68	·939
	36	47 10·57	0·190 01	90	·927
10	1	48 03·31	14	0·073 12	·915
	12	48 55·40	27	35	·903
	13	49 48·14	40	57	·891
	24	50 40·23	53	79	·879
	25	51 32·97	66	0·074 02	·867
	36	52 25·06	79	24	39·855 40·147
11	1	53 17·80	93	47	·135
	12	54 09·88	0·191 06	69	·122
	13	55 02·62	19	92	·110
	24	55 54·71	32	0·075 14	·098
	25	56 47·45	45	36	·086
	36	57 39·54	58	59	·073
12	1	58 32·27	71	81	·061
	12	59 24·36	84	0·076 03	·049
	13	50 00 17·10	98	26	·037
	24	01 09·19	0·192 11	48	·024
	25	02 01·92	24	71	·012
	36	02 54·01	37	93	40·000

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
13	1	50 03 46·75	0·192 50	0·077 16	39·988
	12	04 38·83	63	38	·975
	13	05 31·57	77	60	·963
	24	06 23·66	90	83	·951
	25	07 16·39	0·193 03	0·078 05	·939
	36	08 08·48	16	28	·926
14	1	09 01·22	29	50	·914
	12	09 53·30	43	72	·902
	13	10 46·04	56	95	·890
	24	11 38·12	69	0·079 17	·877
	25	12 30·86	82	40	·865
	36	13 22·95	96	62	39·853 40·149
15	1	14 15·68	0·194 09	85	·136
	12	15 07·77	22	0·080 07	·124
	13	16 00·50	35	30	·112
	24	16 52·59	49	52	·099
	25	17 45·32	62	75	·087
	36	18 37·41	75	97	·074
16	1	19 30·14	89	0·081 20	·062
	12	20 22·22	0·195 02	42	·050
	13	21 14·96	15	64	·037
	24	22 07·04	28	87	·025
	25	22 59·78	42	0·082 09	·012
	36	23 51·86	55	32	40·000
17	1	24 44·59	69	54	39·988
	12	25 36·68	82	77	·975
	13	26 29·41	95	99	·963
	24	27 21·49	0·196 09	0·083 22	·950
	25	28 14·23	22	44	·938
	36	29 06·31	35	67	·925
18	1	29 59·04	49	89	·913
	12	30 51·13	62	0·084 11	·901
	13	31 43·86	76	34	·888
	24	32 35·94	89	56	·876
	25	33 28·67	0·197 02	79	·863
	36	34 20·76	16	0·085 01	39·851 40·150

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township	Section.	Latitude *L.*			Log Sec *L.*	Log Tan *L.*	Quarter Section.
		°	′	″			chains.
19	1	50	35	13·49	0·197 29	0·085 24	40·138
	12		36	05·57	43	46	·125
	13		36	58·30	56	69	·113
	24		37	50·38	69	91	·100
	25		38	43·12	83	0·086 14	·088
	36		39	35·20	96	36	·075
20	1		40	27·93	0·198 10	59	·063
	12		41	20·01	23	81	·050
	13		42	12·74	37	0·087 04	·038
	24		43	04·82	50	26	·025
	25		43	57·55	64	49	·013
	36		44	49·63	77	72	40·000
21	1		45	42·36	91	94	39·987
	12		46	34·44	0·199 04	0·088 17	·975
	13		47	27·18	18	39	·962
	24		48	19·26	31	62	·950
	25		49	11·99	45	84	·937
	36		50	04·07	58	0·089 07	·925
22	1		50	56·80	72	29	·912
	12		51	48·87	85	52	·899
	13		52	41·60	99	74	·887
	24		53	33·68	0·200 13	97	·874
	25		54	26·41	26	0·090 20	·862
	36		55	18·49	40	42	{39·849 40·152
23	1		56	11·22	53	65	·140
	12		57	03·30	67	87	·127
	13		57	56·03	81	0·091 10	·114
	24		58	48·11	94	32	·102
	25		59	40·83	0·201 08	55	·089
	36	51	00	32·91	21	77	·076
24	1		01	25·64	35	0·092 00	·064
	12		02	17·72	49	22	·051
	13		03	10·45	62	45	·038
	24		04	02·52	76	68	·025
	25		04	55·25	90	90	·013
	36		05	47·33	0·202 03	0·093 13	40·000

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
25	1	51 06 40·06	0·202 17	0·093 35	39·987
	12	07 32·13	31	58	·975
	13	08 24·86	44	81	·962
	24	09 16·94	58	0·094 03	·949
	25	10 09·67	72	26	·936
	36	11 01·74	85	48	·924
26	1	11 54·47	99	71	·911
	12	12 46·54	0·203 13	93	·898
	13	13 39·27	27	0·095 16	·885
	24	14 31·35	40	39	·873
	25	15 24·07	54	61	·860
	36	16 16·15	68	84	{39·847 {40·154
27	1	17 08·87	82	0·096 07	·141
	12	18 00·95	95	29	·129
	13	18 53·68	0·204 09	52	·116
	24	19 45·75	23	74	·103
	25	20 38·48	37	97	·090
	36	21 30·55	51	0·097 19	·077
28	1	22 23·28	64	42	·064
	12	23 15·35	78	65	·051
	13	24 08·08	92	87	·039
	24	25 00·15	0·205 06	0·098 10	·026
	25	25 52·87	20	33	·013
	36	26 44·95	33	55	40·000
29	1	27 37·67	47	78	39·987
	12	28 29·75	61	0·099 00	·974
	13	29 22·47	75	23	·961
	24	30 14·54	89	46	·948
	25	31 07·27	0·206 03	69	·936
	36	31 59·34	17	91	·923
30	1	32 52·07	31	0·100 14	·910
	12	33 44·14	44	36	·897
	13	34 36·86	58	59	·884
	24	35 28·93	72	82	·871
	25	36 21·66	86	0·101 05	·858
	36	37 13·73	0·207 00	27	{39·845 {40·156

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*			Log Sec *L.*	Log Tan *L.*	Quarter Section.
		°	′	″			chains.
31	1	51	38	06·45	0·207 14	0·101 50	40·143
	12		38	58·52	28	72	·130
	13		39	51·25	42	95	·117
	24		40	43·32	56	0·102 18	·104
	25		41	36·04	70	41	·091
	36		42	28·11	84	63	·078
32	1		43	20·83	98	86	·065
	12		44	12·91	0·208 12	0·103 08	·052
	13		45	05·63	26	31	·039
	24		45	57·70	40	54	·026
	25		46	50·42	54	77	·013
	36		47	42·49	68	99	40·000
33	1		48	35·21	82	0·104 22	39·987
	12		49	27·28	96	45	·974
	13		50	20·00	0·209 10	67	·961
	24		51	12·07	24	90	·948
	25		52	04·80	38	0·105 13	·935
	36		52	56·87	52	35	·922
34	1		53	49·59	66	58	·909
	12		54	41·66	80	81	·896
	13		55	34·38	94	0·106 04	·883
	24		56	26·45	0·210 08	26	·869
	25		57	19·17	22	49	·856
	36		58	11·24	36	72	{39·843 {40·158
35	1		59	03·95	51	95	·145
	12		59	56·02	65	0·107 17	·132
	13	52	00	48·74	79	40	·119
	24		01	40·81	93	63	·106
	25		02	33·53	0·211 07	86	·092
	36		03	25·60	21	0·108 08	·079
36	1		04	18·32	36	31	·066
	12		05	10·39	50	54	·053
	13		06	03·10	64	77	·040
	24		06	55·17	78	99	·026
	25		07	47·89	92	0·109 22	·013
	36		08	39·96	0·212 06	45	40·000

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
37	1	52 09 32·68	0·212 21	0·109 68	39·987
	12	10 24·74	35	90	·974
	13	11 17·46	49	0·110 13	·960
	24	12 09·53	63	36	·947
	25	13 02·25	77	59	·934
	36	13 54·31	92	81	·921
38	1	14 47·03	0·213 06	0·111 04	·907
	12	15 39·10	20	27	·894
	13	16 31·81	34	50	·881
	24	17 23·88	49	73	·868
	25	18 16·60	63	96	·855
	36	19 08·66	77	0·112 18	{39·841 40·160
39	1	20 01·38	92	41	·147
	12	20 53·45	0·214 06	64	·134
	13	21 46·16	20	87	·120
	24	22 38·23	34	0·113 09	·107
	25	23 30·94	49	32	·093
	36	24 23·01	63	55	·080
40	1	25 15·72	77	78	·067
	12	26 07·79	92	0·114 01	·053
	13	27 00·51	0·215 06	24	·040
	24	27 52·57	20	46	·027
	25	28 45·29	35	69	·013
	36	29 37·35	49	92	40·000
41	1	30 30·06	64	0·115 15	39·987
	12	31 22·13	78	38	·973
	13	32 14·84	92	61	·960
	24	33 06·91	0·216 07	83	·946
	25	33 59·62	21	0·116 06	·933
	36	34 51·69	35	29	·920
42	1	35 44·40	50	52	·906
	12	36 36·46	64	75	·893
	13	37 29·18	79	98	·879
	24	38 21·24	93	0·117 21	·866
	25	39 13·95	0·217 08	44	·853
	36	40 06·02	22	66	{39·839 40·162

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
43	1	52 40 58·73	0·217 37	0·117 89	40·149
	12	41 50·79	51	0·118 12	·135
	13	42 43·51	66	35	·122
	24	43 35·57	80	58	·108
	25	44 28·28	95	81	·095
	36	45 20·35	0·218 09	0·119 04	·081
44	1	46 13·06	24	27	·068
	12	47 05·12	38	49	·054
	13	47 57·83	53	73	·041
	24	48 49·89	67	95	·027
	25	49 42·61	82	0·120 18	·014
	36	50 34·67	96	41	40·000
45	1	51 27·38	0·219 11	64	39·986
	12	52 19·44	25	87	·973
	13	53 12·15	40	0·121 10	·959
	24	54 04·21	54	33	·946
	25	54 56·92	69	56	·932
	36	55 48·98	84	79	·919
46	1	56 41·69	98	0·122 02	·905
	12	57 33·76	0·220 13	25	·891
	13	58 26·47	28	48	·878
	24	59 18·53	42	70	·864
	25	53 00 11·24	57	93	·851
	36	01 03·30	71	0·123 16	{39·837 40·164
47	1	01 56·01	86	39	·151
	12	02 48·07	0·221 01	62	·137
	13	03 40·78	15	85	·123
	24	04 32·84	30	0·124 08	·110
	25	05 25·55	45	31	·096
	36	06 17·61	59	54	·082
48	1	07 10·31	74	77	·068
	12	08 02·37	89	0·125 00	·055
	13	08 55·08	0·222 04	23	·041
	24	09 47·14	18	46	·027
	25	10 39·85	33	69	·014
	36	11 31·91	48	92	40·000

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
49	1	53 12 24·62	0·222 63	0·126 15	39·986
	12	13 16·67	77	38	·973
	13	14 09·38	92	61	·959
	24	15 01·44	0·223 07	84	·945
	25	15 54·15	22	0·127 07	·931
	36	16 46·21	36	30	·918
50	1	17 38·91	51	53	·904
	12	18 30·97	66	76	·890
	13	19 23·68	81	99	·876
	24	20 15·74	96	0·128 22	·863
	25	21 08·44	0·224 10	45	·849
	36	22 00·50	25	68	{39·835 40·166
51	1	22 53·21	40	91	·153
	12	23 45·26	55	0·129 14	·139
	13	24 37·97	70	37	·125
	24	25 30·03	85	60	·111
	25	26 22·73	0·225 00	83	·097
	36	27 14·79	14	0·130 06	·083
52	1	28 07·50	29	30	·069
	12	28 59·55	44	53	·055
	13	29 52·26	59	76	·042
	24	30 44·31	74	99	·028
	25	31 37·02	89	0·131 22	·014
	36	32 29·07	0·226 04	45	40·000
53	1	33 21·78	19	68	39·986
	12	34 13·83	34	91	·972
	13	35 06·54	49	0·132 14	·958
	24	35 58·59	63	37	·944
	25	36 51·30	79	60	·930
	36	37 43·35	93	83	·917
54	1	38 36·06	0·227 08	0·133 07	·903
	12	39 28·11	23	30	·889
	13	40 20·82	38	53	·875
	24	41 12·87	53	76	·861
	25	42 05·58	68	99	·847
	36	42 57·63	83	0·134 22	{39·833 40·169

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
55	1	53 43 50·33	0·227 99	0·134 45	40·155
	12	44 42·39	0·228 13	68	·140
	13	45 35·09	29	91	·126
	24	46 27·14	44	0·135 14	·112
	25	47 19·85	59	38	·098
	36	48 11·90	74	61	·084
56	1	49 04·60	89	84	·070
	12	49 56·65	0·229 04	0·136 07	·056
	13	50 49·36	19	30	·042
	24	51 41·41	34	53	·028
	25	52 34·11	49	77	·014
	36	53 26·17	64	0·137 00	40·000
57	1	54 18·87	79	23	39·986
	12	55 10·92	95	46	·972
	13	56 03·62	0·230 10	69	·958
	24	56 55·67	25	92	·944
	25	57 48·37	40	0·138 16	·930
	36	58 40·43	55	39	·915
58	1	59 33·13	70	62	·901
	12	54 00 25·18	85	85	·887
	13	01 17·88	0·231 01	0·139 08	·873
	24	02 09·93	16	31	·859
	25	03 02·63	31	55	·845
	36	03 54·68	46	78	39·831 40·171
59	1	04 47·38	62	0·140 01	·157
	12	05 39·43	77	24	·142
	13	06 32·13	92	48	·128
	24	07 24·18	0·232 07	71	·114
	25	08 16·88	23	94	·100
	36	09 08·93	38	0·141 17	·085
60	1	10 01·63	53	41	·071
	12	10 53·68	68	64	·057
	13	11 46·38	84	87	·043
	24	12 38·43	99	0·142 10	·028
	25	13 31·13	0·233 14	34	·014
	36	14 23·18	29	57	40·000

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
61	1	54 15 15·88	0·233 45	0·142 80	39·986
	12	16 07·93	60	0·143 03	·971
	13	17 00·63	75	27	·957
	24	17 52·68	91	50	·943
	25	18 45·38	0·234 06	73	·929
	36	19 37·42	21	96	·914
62	1	20 30·12	37	0·144 20	·900
	12	21 22·17	52	43	·886
	13	22 14·87	68	66	·872
	24	23 06·92	83	89	·857
	25	23 59·62	98	0·145 13	·843
	36	24 51·66	0·235 14	36	39·829 40·173
63	1	25 44·36	29	59	·159
	12	26 36·41	45	83	·144
	13	27 29·10	60	0·146 06	·130
	24	28 21·15	75	29	·115
	25	29 13·85	91	53	·101
	36	30 05·90	0·236 06	76	·086
64	1	30 58·59	22	99	·072
	12	31 50·64	37	0·147 22	·058
	13	32 43·34	53	46	·043
	24	33 35·38	68	69	·029
	25	34 28·08	84	93	·014
	36	35 20·12	99	0·148 16	40·000
65	1	36 12·82	0·237 15	39	39·986
	12	37 04·87	30	63	·971
	13	37 57·56	46	86	·957
	24	38 49·61	61	0·149 09	·942
	25	39 42·30	77	33	·928
	36	40 34·35	92	56	·913
66	1	41 27·04	0·238 08	80	·899
	12	42 19·09	24	0·150 03	·884
	13	43 11·78	39	26	·870
	24	44 03·83	55	50	·856
	25	44 56·52	70	73	·841
	36	45 48·57	86	96	39·827 40·175

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
67	1	54 46 41·26	0·239 02	0·151 20	40·161
	12	47 33·31	17	43	·146
	13	48 26·00	33	67	·131
	24	49 18·04	49	90	·117
	25	50 10·74	64	0·152 14	·102
	36	51 02·78	80	37	·088
68	1	51 55·48	96	60	·073
	12	52 47·52	0·240 11	84	·058
	13	53 40·21	27	0·153 07	·044
	24	54 32·26	43	31	·029
	25	55 24·95	58	54	·015
	36	56 16·99	74	77	40·000
69	1	57 09·69	90	0·154 01	39·985
	12	58 01·73	0·241 05	24	·971
	13	58 54·42	21	48	·956
	24	59 46·46	37	71	·941
	25	55 00 39·16	53	95	·927
	36	01 31·20	68	0·155 18	·912
70	1	02 23·89	84	42	·898
	12	03 15·93	0·242 00	65	·883
	13	04 08·62	16	89	·868
	24	05 00·67	31	0·156 12	·854
	25	05 53·36	47	36	·839
	36	06 45·40	63	59	39·824 40·177
71	1	07 38·09	79	83	·163
	12	08 30·13	95	0·157 06	·148
	13	09 22·82	0·243 11	30	·133
	24	10 14·86	26	53	·118
	25	11 07·56	42	77	·104
	36	11 59·60	58	0·158 00	·089
72	1	12 52·29	74	24	·074
	12	13 44·33	90	47	·059
	13	14 37·02	0·244 06	71	·044
	24	15 29·06	22	94	·030
	25	16 21·75	38	0·159 18	·015
	36	17 13·79	53	41	40·000

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
73	1	55 18 06·48	0·244 69	0·159 65	39·985
	12	18 58·52	85	89	·970
	13	19 51·21	0·245 01	0·160 12	·956
	24	20 43·25	17	36	·941
	25	21 35·94	33	59	·926
	36	22 27·98	49	83	·911
74	1	23 20·67	65	0·161 07	·896
	12	24 12·70	81	30	·881
	13	25 05·39	97	54	·867
	24	25 57·43	0·246 13	77	·852
	25	26 50·12	29	0·162 01	·837
	36	27 42·16	45	24	39·822 40·180
75	1	28 34·85	61	48	·165
	12	29 26·89	77	72	·150
	13	30 19·57	93	95	·135
	24	31 11·61	0·247 09	0·163 19	·120
	25	32 04·30	25	43	·105
	36	32 56·34	41	66	·090
76	1	33 49·02	57	90	·075
	12	34 41·06	73	0·164 13	·060
	13	35 33·75	90	37	·045
	24	36 25·79	0·248 06	61	·030
	25	37 18·47	22	85	·015
	36	38 10·51	38	0·165 08	40·000
77	1	39 03·20	54	32	39·985
	12	39 55·23	70	55	·970
	13	40 47·92	86	79	·955
	24	41 39·96	0·249 02	0·166 03	·940
	25	42 32·64	19	27	·925
	36	43 24·68	35	50	·910
78	1	44 17·37	51	74	·895
	12	45 09·40	67	97	·880
	13	46 02·09	83	0·167 21	·865
	24	46 54·12	0·250 00	45	·850
	25	47 46·81	16	69	·835
	36	48 38·85	32	92	39·820 40·182

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
79	1	55 49 31·53	0·250 48	0·168 16	40·167
	12	50 23·57	64	40	·152
	13	51 16·25	81	64	·137
	24	52 08·29	97	87	·122
	25	53 00·97	0·251 13	0·169 11	·106
	36	53 53·01	30	35	·091
80	1	54 45·69	46	59	·076
	12	55 37·72	62	82	·061
	13	56 30·41	79	0·170 06	·046
	24	57 22·44	95	30	·030
	25	58 15·13	0·252 11	54	·015
	36	59 07·16	27	77	40·000
81	1	59 59·84	44	0·171 01	39·985
	12	56 00 51·88	60	25	·970
	13	01 44·56	77	49	·954
	24	02 36·60	93	72	·939
	25	03 29·28	0·253 09	96	·924
	36	04 21·31	26	0·172 20	·909
82	1	05 14·00	42	44	·893
	12	06 06·03	58	68	·878
	13	06 58·71	75	92	·863
	24	07 50·74	91	0·173 15	·848
	25	08 43·43	0·254 08	39	·833
	36	09 35·46	24	63	{39·817 40·185
83	1	10 28·14	41	87	·169
	12	11 20·17	57	0·174 11	·154
	13	12 12·86	74	35	·138
	24	13 04·89	90	58	·123
	25	13 57·57	0·255 06	82	·108
	36	14 49·60	23	0·175 06	·092
84	1	15 42·28	39	30	·077
	12	16 34·31	56	54	·062
	13	17 27·00	72	78	·046
	24	18 19·03	89	0·176 01	·031
	25	19 11·71	0·256 06	26	·015
	36	20 03·74	22	49	40·000

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
85	1	56 20 56·42	0·256 39	0·176 73	39·985
	12	21 48·45	55	97	·969
	13	22 41·13	72	0·177 21	·954
	24	23 33·16	88	45	·938
	25	24 25·84	0·257 05	69	·923
	36	25 17·87	21	93	·908
86	1	26 10·55	38	0·178 17	·892
	12	27 02·58	55	41	·877
	13	27 55·26	71	65	·861
	24	28 47·29	88	88	·846
	25	29 39·97	0·258 05	0·179 13	·830
	36	30 32·00	21	36	{39·815 40·187
87	1	31 24·68	38	60	·171
	12	32 16·71	55	84	·156
	13	33 09·39	71	0·180 08	·140
	24	34 01·42	88	32	·125
	25	34 54·10	0·259 05	56	·109
	36	35 46·12	21	80	·093
88	1	36 38·80	38	0·181 04	·078
	12	37 30·83	55	28	·062
	13	38 23·51	72	52	·047
	24	39 15·54	88	76	·031
	25	40 08·21	0·260 05	0·182 00	·015
	36	41 00·24	22	24	40·000
89	1	41 52·92	39	48	39·984
	12	42 44·95	55	72	·969
	13	43 37·63	72	96	·953
	24	44 29·65	89	0·183 20	·937
	25	45 22·33	0·261 06	44	·922
	36	46 14·36	23	68	·906
90	1	47 07·03	40	93	·891
	12	47 59·06	56	0·184 16	·875
	13	48 51·74	73	41	·859
	24	49 43·76	90	65	·844
	25	50 36·44	0·262 07	89	·828
	36	51 28·47	24	0·185 13	{39·813 40·190

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
91	1	56 52 21·14	0·262 41	0·185 37	40·174
	12	53 13·17	58	61	·158
	13	54 05·85	75	85	·142
	24	54 57·87	91	0·186 09	·126
	25	55 50·55	0·263 08	33	·111
	36	56 42·57	25	57	·095
92	1	57 35·25	42	82	·079
	12	58 27·27	59	0·187 06	·063
	13	59 19·95	76	30	·047
	24	57 00 11·98	93	54	·032
	25	01 04·65	0·264 10	78	·016
	36	01 56·68	27	0·188 02	40·000
93	1	02 49·35	44	26	39·984
	12	03 41·38	61	50	·968
	13	04 34·05	78	75	·953
	24	05 26·07	95	99	·937
	25	06 18·75	0·265 12	0·189 23	·921
	36	07 10·77	29	47	·905
94	1	08 03·45	46	71	·889
	12	08 55·47	63	95	·873
	13	09 48·14	80	0·190 20	·858
	24	10 40·17	97	44	·842
	25	11 32·84	0·266 15	68	·826
	36	12 24·87	32	92	39·810 40·192
95	1	13 17·54	49	0·191 17	·176
	12	14 09·56	66	41	·160
	13	15 02·24	83	65	·144
	24	15 54·26	0·267 00	89	·128
	25	16 46·93	17	0·192 13	·112
	36	17 38·95	34	38	·096
96	1	18 31·63	52	62	·080
	12	19 23·65	69	86	·064
	13	20 16·32	86	0·193 10	·048
	24	21 08·34	0·268 03	35	·032
	25	22 01·02	20	59	·016
	36	22 53·04	38	83	40·000

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
97	1	57 23 45·71	0·268 55	0·194 07	39·984
	12	24 37·73	72	32	·968
	13	25 30·40	89	56	·952
	24	26 22·42	0·269 07	80	·936
	25	27 15·10	24	0·195 05	·920
	36	28 07·12	41	29	·904
98	1	28 59·79	58	53	·888
	12	29 51·81	76	77	·872
	13	30 44·48	93	0·196 02	·856
	24	31 36·50	0·270 10	26	·840
	25	32 29·17	28	51	·824
	36	33 21·19	45	75	39·808 40·195
99	1	34 13·86	62	99	·178
	12	35 05·88	80	0·197 24	·162
	13	35 58·55	97	48	·146
	24	36 50·57	0·271 14	72	·130
	25	37 43·24	32	97	·114
	36	38 35·26	49	0·198 21	·097
100	1	39 27·93	67	45	·081
	12	40 19·95	84	70	·065
	13	41 12·62	0·272 01	94	·049
	24	42 04·64	19	0·199 19	·032
	25	42 57·31	36	43	·016
	36	43 49·33	54	67	40·000
101	1	44 42·00	71	92	39·984
	12	45 34·02	89	0·200 16	·968
	13	46 26·69	0·273 06	41	·951
	24	47 18·70	24	65	·935
	25	48 11·37	41	90	·919
	36	49 03·39	59	0·201 14	·902
102	1	49 56·06	76	39	·886
	12	50 48·08	94	63	·870
	13	51 40·74	0·274 11	87	·854
	24	52 32·76	29	0·202 12	·837
	25	53 25·43	46	36	·821
	36	54 17·45	64	61	39·805 40·197

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*			Log Sec *L.*	Log Tan *L.*	Quarter Section.
		°	′	″			chains.
103	1	57	55	10·12	0·274 82	0·202 85	40·181
	12		56	02·13	99	0·203 10	·165
	13		56	54·80	0·275 17	34	·148
	24		57	46·82	34	59	·132
	25		58	39·48	52	83	·115
	36		59	31·50	69	0·204 08	·099
104	1	58	00	24·17	87	32	·082
	12		01	16·18	0·276 05	57	·066
	13		02	08·85	23	81	·049
	24		03	00·87	40	0·205 06	·033
	25		03	53·53	58	31	·017
	36		04	45·55	75	55	40·000
105	1		05	38·22	93	80	39·984
	12		06	30·23	0·277 11	0·206 04	·967
	13		07	22·90	29	29	·951
	24		08	14·91	46	53	·934
	25		09	07·58	64	78	·918
	36		09	59·59	82	0·207 02	·901
106	1		10	52·26	0·278 00	27	·885
	12		11	44·27	17	52	·868
	13		12	36·94	35	76	·852
	24		13	28·95	53	0·208 01	·835
	25		14	21·62	71	26	·819
	36		15	13·63	88	50	{39·802 40·200
107	1		16	06·30	0·279 06	75	·183
	12		16	58·31	24	99	·167
	13		17	50·98	42	0·209 24	·150
	24		18	42·99	60	49	·133
	25		19	35·66	78	73	·117
	36		20	27·67	95	98	·100
108	1		21	20·33	0·280 13	0·210 23	·083
	12		22	12·35	31	47	·067
	13		23	05·01	49	72	·050
	24		23	57·02	67	97	·033
	25		24	49·69	85	0·211 22	·017
	36		25	41·70	0·281 03	46	40·000

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
109	1	58 26 34·36	0·281 21	0·211 71	39·983
	12	27 26·38	39	95	·967
	13	28 19·04	57	0·212 20	·950
	24	29 11·05	75	45	·933
	25	30 03·72	93	70	·916
	36	30 55·73	0·282 11	94	·900
110	1	31 48·39	29	0 213 19	·883
	12	32 40·40	47	44	·866
	13	33 33·06	65	69	·850
	24	34 25·08	83	93	·833
	25	35 17·74	0·283 01	0·214 18	·816
	36	36 09·75	19	43	{39·800 40·203
111	1	37 02·41	37	68	·186
	12	37 54·42	55	93	·169
	13	38 47·08	73	0·215 17	·152
	24	39 39·10	91	42	·135
	25	40 31·76	0·284 09	67	·118
	36	41 23·77	27	92	·101
112	1	42 16·43	46	0·216 17	·085
	12	43 08·44	64	41	·068
	13	44 01·10	82	66	·051
	24	44 53·11	0·285 00	91	·034
	25	45 45·77	18	0·217 16	·017
	36	46 37·78	36	41	40·000
113	1	47 30·44	55	66	39·983
	12	48 22·45	73	91	·966
	13	49 15·11	91	0·218 16	·949
	24	50 07·12	0·286 09	40	·932
	25	50 59·78	27	65	·915
	36	51 51·79	45	90	·898
114	1	52 44·45	64	0·219 15	·881
	12	53 36·46	82	40	·865
	13	54 29·12	0·287 00	65	·848
	24	55 21·13	18	90	·831
	25	56 13·79	37	0·220 15	·814
	36	57 05·80	55	40	{39·797 40·206

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
115	1	58 57 58·45	0·287 73	0·220 65	40·189
	12	58 50·46	92	89	·171
	13	59 43·12	0·288 10	0·221 15	·154
	24	59 00 35·13	28	39	·137
	25	01 27·79	47	65	·120
	36	02 19·80	65	89	·103
116	1	03 12·45	84	0·222 14	·086
	12	04 04·46	0·289 02	39	·069
	13	04 57·12	20	64	·051
	24	05 49·13	39	89	·034
	25	06 41·79	57	0·223 14	·017
	36	07 33·79	75	39	40·000
117	1	08 26·45	94	64	39·983
	12	09 18·46	0·290 12	89	·966
	13	10 11·11	31	0·224 15	·948
	24	11 03·12	49	39	·931
	25	11 55·78	68	65	·914
	36	12 47·78	86	90	·897
118	1	13 40·44	0·291 05	0·225 15	·880
	12	14 32·45	23	40	·863
	13	15 25·10	42	65	·845
	24	16 17·11	60	90	·828
	25	17 09·77	79	0·226 15	·811
	36	18 01·77	97	40	{39·794 40·209
119	1	18 54·43	0·292 16	65	·191
	12	19 46·43	35	90	·174
	13	20 39·09	53	0·227 15	·156
	24	21 31·10	72	40	·139
	25	22 23·75	90	66	·122
	36	23 15·76	0·293 09	91	·104
120	1	24 08·41	28	0·228 16	·087
	12	25 00·42	46	41	·070
	13	25 53·07	65	66	·052
	24	26 45·08	84	91	·035
	25	27 37·73	0·294 02	0·229 17	·017
	36	28 29·74	21	42	40·000

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
121	1	59 29 22·39	0·294 40	0·229 67	39·983
	12	30 14·39	58	92	·965
	13	31 07·05	77	0·230 17	·948
	24	31 59·05	96	43	·930
	25	32 51·71	0·295 15	68	·913
	36	33 43·71	33	93	·896
122	1	34 36·36	52	0·231 18	·878
	12	35 28·37	71	43	·861
	13	36 21·02	90	69	·843
	24	37 13·02	0·296 08	94	·826
	25	38 05·68	27	0·232 19	·808
	36	38 57·68	46	44	39·791 40·212
123	1	39 50·33	65	70	·194
	12	40 42·34	84	95	·176
	13	41 34·99	0·297 02	0·233 20	·159
	24	42 26·99	21	46	·141
	25	43 19·65	40	71	·123
	36	44 11·65	59	96	·106
124	1	45 04·30	78	0·234 22	·088
	12	45 56·30	97	47	·071
	13	46 48·96	0·298 16	72	·053
	24	47 40·96	35	97	·035
	25	48 33·61	54	0·235 23	·018
	36	49 25·61	72	48	40·000
125	1	50 18·26	92	74	39·982
	12	51 10·26	0·299 10	99	·965
	13	52 02·91	29	0·236 24	·947
	24	52 54·92	48	50	·929
	25	53 47·57	67	75	·912
	36	54 39·57	86	0·237 00	·894
126	1	55 32·22	0·300 05	26	·876
	12	56 24·22	24	51	·859
	13	57 16·87	44	77	·841
	24	58 08·87	63	0·238 02	·824
	25	59 01·52	82	28	·806
	36	59 53·52	0·301 01	53	39·788 40·215

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
127	1	60 00 46·17	0·301 20	0·238 79	40·197
	12	01 38·17	39	0·239 04	·179
	13	02 30·82	58	29	·161
	24	03 22·82	77	55	·143
	25	04 15·47	96	80	·125
	36	05 07·47	0·302 15	0·240 06	·107
128	1	06 00·12	35	31	·089
	12	06 52·12	54	57	·072
	13	07 44·77	73	82	·054
	24	08 36·77	92	0·241 08	·036
	25	09 29·42	0·303 11	33	·018
	36	10 21·42	30	59	40·000
129	1	11 14·07	50	84	39·982
	12	12 06·06	69	0·242 10	·964
	13	12 58·71	88	36	·946
	24	13 50·71	0·304 07	61	·928
	25	14 43·36	27	87	·910
	36	15 35·36	46	0·243 12	·893
130	1	16 28·01	65	38	·875
	12	17 20·00	84	63	·857
	13	18 12·65	0·305 04	89	·839
	24	19 04·65	23	0·244 14	·821
	25	19 57·30	43	40	·803
	36	20 49·30	62	66	{39·785 40·218
131	1	21 41·94	81	91	·199
	12	22 33·94	0·306 01	0·245 17	·181
	13	23 26·59	20	43	·163
	24	24 18·58	39	68	·145
	25	25 11·23	59	94	·127
	36	26 03·23	78	0·246 20	·109
132	1	26 55·88	98	45	·091
	12	27 47·87	0·307 17	71	·073
	13	28 40·52	37	97	·054
	24	29 32·51	56	0·247 22	·036
	25	30 25·16	75	48	·018
	36	31 17·16	95	74	40·000

TABLE X.—*Continued.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*	Log Sec *L.*	Log Tan *L.*	Quarter Section.
		° ′ ″			chains.
133	1	60 32 09·80	0·308 14	0·248 00	39·982
	12	33 01·80	34	25	·964
	13	33 54·44	53	51	·946
	24	34 46·44	73	77	·927
	25	35 39·09	93	0·249 03	·909
	36	36 31·08	0·309 12	28	·891
134	1	37 23·73	32	54	·873
	12	38 15·72	51	80	·855
	13	39 08·37	71	0·250 06	·837
	24	40 00·36	90	31	·818
	25	40 53·01	0·310 10	57	·800
	36	41 45·00	30	83	39·782 40·221
135	1	42 37·65	49	0·251 09	·202
	12	43 29·64	69	34	·184
	13	44 22·29	89	60	·165
	24	45 14·28	0·311 08	86	·147
	25	46 06·92	28	0·252 12	·129
	36	46 58·92	48	38	·110
136	1	47 51·56	67	64	·092
	12	48 43·56	87	90	·074
	13	49 36·20	0·312 07	0·253 16	·055
	24	50 28·19	26	41	·037
	25	51 20·84	46	67	·018
	36	52 12·83	66	93	40·000
137	1	53 05·47	86	0·254 19	39·981
	12	53 57·47	0·313 05	45	·963
	13	54 50·11	25	71	·945
	24	55 42·10	45	97	·926
	25	56 34·75	65	0·255 23	·908
	36	57 26·74	85	49	·889
138	1	58 19·38	0·314 05	75	·871
	12	59 11·37	24	0·256 01	·853
	13	61 00 04·02	44	27	·834
	24	00 56·01	64	53	·816
	25	01 48·65	84	79	·797
	36	02 40·64	0·315 04	0·257 05	39·779 40·224

TABLE X.—*Concluded.*

Latitude, etc., for the North Boundary of each Section.

Third System of Survey.

Township.	Section.	Latitude *L.*			Log Sec *L.*	Log Tan *L.*	Quarter Section.
		°	′	″			chains.
139	1	61	03	33·28	0·315 24	0·257 31	40·205
	12		04	25·28	44	57	·187
	13		05	17·92	64	83	·168
	24		06	09·91	84	0·258 09	·149
	25		07	02·55	0·316 04	35	·131
	36		07	54·54	24	61	·112
140	1		08	47·18	44	87	·093
	12		09	39·17	64	0·259 13	·075
	13		10	31·81	84	39	·056
	24		11	23·81	0·317 04	65	·037
	25		12	16·45	24	91	·019
	36		13	08·44	44	0·260 17	40·000
141	1		14	01·08	64	44	39·981
	12		14	53·07	84	69	·963
	13		15	45·71	0·318 04	96	·944
	24		16	37·70	24	0·261 22	·925
	25		17	30·34	44	48	·906
	36		18	22·33	64	74	·888
142	1		19	14·97	85	0·262 00	·869
	12		20	06·96	0·319 05	26	·851
	13		20	59·60	25	53	·832
	24		21	51·59	45	79	·813
	25		22	44·23	65	0·263 05	·794
	36		23	36·22	85	31	{39·776 40·227
143	1		24	28·85	0·320 06	57	·208
	12		25	20·84	26	84	·189
	13		26	13·48	46	0·264 10	·170
	24		27	05·47	66	36	·151
	25		27	58·11	86	62	·133
	36		28	50·10	0·321 07	88	·114
144	1		29	42·74	27	0·265 15	·095
	12		30	34·73	47	41	·076
	13		31	27·36	68	67	·057
	24		32	19·35	88	94	·038
	25		33	11·99	0·322 08	0·266 20	·019
	36		34	03·98	28	46	40·000

TABLE XI.

Showing the difference of Latitude between Township Corners and Section and Quarter Section Posts on a Township Chord.

Number of Line.	*dL* For ½ sec. from Corner.	*dL* For 1 sec. from Corner.	*dL* For 1½ secs. from Corner.	*dL* For 2 secs. from Corner.	*dL* For 2½ secs. from Corner.	*dL* For 3 secs. from Corner.
1st Base....	0″·02 lks.	0″·04 lks.	0″·05 lks.	0″·06 lks.	0″·07 lks.	0″·07 lks.
do	3·2	5·9	8·0	9·5	10·3	10·7
11th Base...	0″·02 lks.	0″·04 lks.	0″·06 lks.	0″·07 lks.	0″·08 lks.	0″·08 lks.
do ...	3·6	6·7	9·0	10·7	11·7	12·1
21st Base...	0″·03 lks.	0″·05 lks.	0″·07 lks.	0″·08 lks.	0″·09 lks.	0″·09 lks.
do ...	4·2	7·6	10·3	12·2	13·3	13·7
31st Base...	0″·03 lks.	0″·06 lks.	0″·08 lks.	0″·09 lks.	0″·10 lks.	0″·10 lks.
do ...	4·8	8·7	11·8	14·0	15·3	15·7

TABLE XII.

For Converting Logarithmic Tangents of Small Arcs into Logarithms of Seconds of Arc.

Log Tan.	Log *T*.	Log Tan.	Log *T*.	Log Tan.	Log *T*.
7·773	5·314 42	8·409	5·314 33	8·553	5·314 24
8·009	41	·431	32	·565	23
·120	40	·450	31	·576	22
·192	39	·468	30	·586	21
·247	38	·485	29	·596	20
·290	37	·501	28	·605	19
·327	36	·515	27	·614	18
·358	35	·529	26	·623	17
·385	34	·541	25	·632	16

TABLE XIII.

$$\text{Log}\,\frac{1}{1-m}$$

m positive

that is, when t lies between 0^h and 6^h, or 18^h and 24^h.

Log m	0	1	2	3	4	5	6	7	8	9
5·	0·00 000	001	001	001	001	001	002	002	003	003
6·0	004	004	005	005	005	005	005	005	005	005
1	006	006	006	006	006	006	006	006	007	007
2	007	007	007	007	008	008	008	008	008	009
3	009	009	009	009	010	010	010	010	010	011
4	011	011	011	012	012	012	013	013	013	013
5	014	014	014	015	015	015	016	016	017	017
6	017	018	018	019	019	019	020	020	021	021
7	022	022	023	023	024	024	025	026	026	027
8	027	028	029	029	030	031	032	032	033	034
9	035	035	036	037	038	039	040	041	042	043
7·0	044	045	046	047	048	049	050	051	052	054
1	055	056	057	059	060	061	063	064	066	067
2	069	071	072	074	076	077	079	081	083	085
3	087	089	091	093	095	097	100	102	104	107
4	109	112	114	117	120	123	125	128	131	134
5	138	141	144	147	151	154	158	162	165	169
6	173	177	181	186	190	194	199	204	208	213
7	218	223	229	234	239	245	251	257	263	269
8	275	281	288	295	302	309	316	323	331	338
9	346	355	363	371	380	389	398	407	417	427
8·00	437	438	439	440	441	442	443	444	445	446
01	447	448	449	450	451	452	453	454	455	456
02	457	458	459	460	461	463	464	465	466	467
03	468	469	470	471	472	473	474	476	477	478
04	479	480	481	482	483	484	486	487	488	489
05	490	491	492	494	495	496	497	498	499	500
06	502	503	504	505	506	507	509	510	511	512
07	513	515	516	517	518	519	521	522	523	524
08	525	527	528	529	530	531	533	534	535	536
09	538	539	540	541	543	544	545	546	548	549
8·10	0·00 550	552	553	554	555	557	558	559	561	562

TABLE XIII.—*Continued.*

$$\text{Log}\frac{1}{1-m}$$

m negative

that is, when *t* lies between 6^h and 18^h.

Log *m*	0	1	2	3	4	5	6	7	8	9
5· *n*	10·00 000 / 9·99	999	999	999	999	999	998	998	997	997
6·0 *n*	9·99 996	996	996	995	995	995	995	995	995	995
1 *n*	995	994	994	994	994	994	994	994	993	993
2 *n*	993	993	993	993	993	992	992	992	992	992
3 *n*	991	991	991	991	991	990	990	990	990	989
4 *n*	989	989	989	988	988	988	988	987	987	987
5 *n*	986	986	986	985	985	985	984	984	984	983
6 *n*	983	982	982	982	981	981	980	980	979	979
7 *n*	978	978	977	977	976	976	975	974	974	973
8 *n*	973	972	971	971	970	969	969	968	967	966
9 *n*	966	965	964	963	962	961	960	960	959	958
7·0 *n*	957	956	955	954	952	951	950	949	948	947
1 *n*	945	944	943	942	940	939	937	936	934	933
2 *n*	931	930	928	926	925	923	921	919	917	915
3 *n*	913	911	909	907	905	903	901	898	896	894
4 *n*	891	889	886	883	881	878	875	872	869	866
5 *n*	863	860	856	853	850	846	843	839	835	831
6 *n*	827	823	819	815	811	806	802	797	793	788
7 *n*	783	778	773	767	762	757	751	745	739	733
8 *n*	727	721	714	707	701	694	687	679	672	664
9 *n*	656	648	640	632	623	615	606	597	587	578
8·00*n*	568	567	566	565	564	563	562	561	560	559
01*n*	558	557	556	555	554	553	552	551	550	549
02*n*	548	547	546	545	543	542	541	540	539	538
03*n*	537	536	535	534	533	532	531	530	529	528
04*n*	526	525	524	523	522	521	520	519	518	517
05*n*	515	514	513	512	511	510	509	508	507	505
06*n*	504	503	502	501	500	499	497	496	495	494
07*n*	493	492	490	489	488	487	486	485	483	482
08*n*	481	480	479	477	476	475	474	473	471	470
09*n*	469	468	467	465	464	463	462	460	459	458
8·10*n*	9·99 457	455	454	453	452	450	449	448	447	445

TABLE XIII.—*Continued.*

$$\text{Log}\,\frac{1}{1-m}$$

m positive

that is, when *t* lies between 0^h and 6^h, or 18^h and 24^h.

Log *m*	0	1	2	3	4	5	6	7	8	9
8·10	0·00 550	552	553	554	555	557	558	559	561	562
11	563	564	566	567	568	570	571	572	574	575
12	576	578	579	580	582	583	584	586	587	589
13	590	591	593	594	595	597	598	600	601	602
14	604	605	607	608	609	611	612	614	615	616
15	618	619	621	622	624	625	627	628	629	631
16	632	634	635	637	638	640	641	643	644	646
17	647	649	650	652	653	655	656	658	659	661
18	662	664	665	667	669	670	672	673	675	676
19	678	680	681	683	684	686	687	689	691	692
8·20	694	695	697	699	700	702	704	705	707	709
21	710	712	713	715	717	718	720	722	723	725
22	727	729	730	732	734	735	737	739	740	742
23	744	746	747	749	751	753	754	756	758	760
24	761	763	765	767	769	770	772	774	776	777
25	779	781	783	785	787	788	790	792	794	796
26	798	799	801	803	805	807	809	811	813	814
27	816	818	820	822	824	826	828	830	832	834
28	836	838	839	841	843	845	847	849	851	853
29	855	857	859	861	863	865	867	869	871	873
8·30	875	877	879	881	884	886	888	890	892	894
31	896	898	900	902	904	906	909	911	913	915
32	917	919	921	923	926	928	930	932	934	936
33	939	941	943	945	947	950	952	954	956	958
34	961	963	965	967	970	972	974	977	979	981
35	983	986	988	990	993	995	997	**000**	**002**	**004**
36	0·01 007	009	011	014	016	018	021	023	025	028
37	030	033	035	037	040	042	045	047	050	052
38	055	057	059	062	064	067	069	072	074	077
39	079	082	084	087	090	092	095	097	100	102
8·40	0·01 105	107	110	113	115	118	120	123	126	128

TABLE XIII.—*Continued.*

$$\text{Log } \frac{1}{1-m}$$

m negative

that is, when *t* lies between 6^h and 18^h.

Log *m*	0	1	2	3	4	5	6	7	8	9
$8\cdot10_n$	9·99 457	455	454	453	452	450	449	448	447	445
11_n	444	443	442	440	439	438	436	435	434	433
12_n	431	430	429	427	426	425	423	422	421	419
13_n	418	417	415	414	413	411	410	409	407	406
14_n	405	403	402	401	399	398	396	395	394	392
15_n	391	389	388	387	385	384	382	381	380	378
16_n	377	375	374	373	371	370	368	367	365	364
17_n	362	361	359	358	357	355	354	352	351	349
18_n	348	346	345	343	342	340	339	337	336	334
19_n	333	331	330	328	326	325	323	322	320	319
$8\cdot20_n$	317	316	314	312	311	309	308	306	305	303
21_n	301	300	298	297	295	293	292	290	288	287
22_n	285	284	282	280	279	277	275	274	272	270
23_n	269	267	265	264	262	260	259	257	255	254
24_n	252	250	248	247	245	243	241	240	238	236
25_n	235	233	231	229	228	226	224	222	220	219
26_n	217	215	213	211	210	208	206	204	202	201
27_n	199	197	195	193	191	190	188	186	184	182
28_n	180	178	177	175	173	171	169	167	165	163
29_n	161	159	158	156	154	152	150	148	146	144
$8\cdot30_n$	142	140	138	136	134	132	130	128	126	124
31_n	122	120	118	116	114	112	110	108	106	104
32_n	102	100	098	096	094	092	090	088	086	083
33_n	081	079	077	075	073	071	069	066	064	062
34_n	060	058	056	054	052	049	047	045	043	041
35_n	039	036	034	032	030	027	025	023	021	019
36_n	016	014	012	010	007	005	003	001	**998**	**996**
37_n	9·98 994	991	989	987	985	982	980	978	975	973
38_n	971	968	966	963	961	959	956	954	952	949
39_n	947	944	942	940	937	935	932	930	928	925
$8\cdot40_n$	9·98 923	920	918	915	913	910	908	905	903	900

TABLE XIII.—*Continued.*

$$\text{Log } \frac{1}{1-m}$$

m positive

that is, when *t* lies between 0^h and 6^h, or 18^h and 24^h.

Log *m*	0	1	2	3	4	5	6	7	8	9
8·40	0·01 105	107	110	113	115	118	120	123	126	128
41	131	134	136	139	142	144	147	150	152	155
42	158	160	163	166	169	171	174	177	179	182
43	185	188	191	193	196	199	202	205	207	210
44	213	216	219	222	224	227	230	233	236	239
45	242	245	247	250	253	256	259	262	265	268
46	271	274	277	280	283	286	289	292	295	298
47	301	304	307	310	313	316	319	323	326	329
48	332	335	338	341	344	347	351	354	357	360
49	363	367	370	373	376	379	383	386	389	392
8·50	396	399	402	405	409	412	415	419	422	425
51	429	432	435	439	442	445	449	452	456	459
52	462	466	469	473	476	480	483	487	490	494
53	497	501	504	508	511	515	518	522	525	529
54	533	536	540	543	547	551	554	558	562	565
55	569	573	576	580	584	587	591	595	599	602
56	606	610	614	618	621	625	629	633	637	640
57	644	648	652	656	660	664	668	672	676	679
58	683	687	691	695	699	703	707	711	715	719
59	723	727	732	736	740	744	748	752	756	760
8·60	0·01 764	768	773	777	781	785	789	794	798	802

TABLE XIII.—*Concluded.*

$$\text{Log } \frac{1}{1-m}$$

m negative

that is, when *t* lies between 6^h and 18^h.

Log *n*	0	1	2	3	4	5	6	7	8	9
$8\cdot40_n$	9·98 923	920	918	915	913	910	908	905	903	900
41_n	898	895	893	890	888	885	883	880	878	875
42_n	873	870	867	865	862	860	857	854	852	849
43_n	847	844	841	839	836	833	831	828	825	823
44_n	820	817	815	812	809	807	804	801	798	796
45_n	793	790	787	785	782	779	776	774	771	768
46_n	765	762	760	757	754	751	748	745	743	740
47_n	737	734	731	728	725	722	720	717	714	711
48_n	708	705	702	699	696	693	690	687	684	681
49_n	678	675	672	669	666	663	660	657	654	651
$8\cdot50_n$	648	645	642	639	636	633	629	626	623	620
51_n	617	614	611	608	604	601	598	595	592	588
52_n	585	582	579	576	572	569	566	563	559	556
53_n	553	550	546	543	540	536	533	530	526	523
54_n	520	516	513	510	506	503	499	496	493	489
55_n	486	482	479	476	472	469	465	462	458	455
56_n	451	448	444	441	437	434	430	426	423	419
57_n	416	412	409	405	401	398	394	390	387	383
58_n	380	376	372	368	365	361	357	354	350	346
59_n	342	339	335	331	327	324	320	316	312	308
$8\cdot60_n$	9·98 305	301	297	293	289	285	281	278	274	270

TABLE XIV.

Deflection of a Trial Line for Deviations from 1 to 149 Links at the end of Eighty-one Chains.

Links.	Decimal Division.	Sexagesimal Division.		Links.	Decimal Division.	Sexagesimal Division.		Links.	Decimal Division.	Sexagesimal Division.	
	°	′	″		°	′	″		°	′	″
0	0·000	0	00	35	0·248	14	51	70	0·495	29	43
1	·007		25	36	·255	15	17	71	·502	30	08
2	·014		51	37	·262		42	72	·509		33
3	·021	1	16	38	·269	16	08	73	·516		59
4	·028		42	39	·276		33	74	·523	31	24
5	·035	2	07	40	·283		59	75	·531		50
6	·042		33	41	·290	17	24	76	·538	32	15
7	·050		58	42	·297		50	77	·545		41
8	·057	3	24	43	·304	18	15	78	·552	33	06
9	·064		49	44	·311		40	79	·559		32
10	·071	4	15	45	·318	19	06	80	·566		57
11	·078		40	46	·325		31	81	·573	34	23
12	·085	5	06	47	·332		57	82	·580		48
13	·092		31	48	·340	20	22	83	·587	35	13
14	·099		57	49	·347		48	84	·594		39
15	·106	6	22	50	·354	21	13	85	·601	36	04
16	·113		47	51	·361		39	86	·608		30
17	·120	7	13	52	·368	22	04	87	·615		55
18	·127		38	53	·375		30	88	·622	37	21
19	·134	8	04	54	·382		55	89	·630		46
20	·141		29	55	·389	23	21	90	·637	38	12
21	·149		55	56	·396		46	91	·644		37
22	·156	9	20	57	·403	24	11	92	·651	39	03
23	·163		46	58	·410		37	93	·658		28
24	·170	10	11	59	·417	25	02	94	·665		54
25	·177		37	60	·424		28	95	·672	40	19
26	·184	11	02	61	·431		53	96	·679		44
27	·191		28	62	·439	26	19	97	·686	41	10
28	·198		53	63	·446		44	98	·693		35
29	·205	12	18	64	·453	27	10	99	·700	42	01
30	·212		44	65	·460		35	100	·707		26
31	·219	13	09	66	·467	28	01	101	·714		52
32	·226		35	67	·474		26	102	·721	43	17
33	·233	14	00	68	·481		52	103	·729		43
34	·241		26	69	·488	29	17	104	·736	44	08

TABLE XIV.—*Concluded.*

Deflection of a Trial Line for Deviations from 1 to 149 Links at the end of Eighty-one Chains.

Links.	Decimal Division.	Sexagesimal Division.		Links.	Decimal Division.	Sexagesimal Division.		Links.	Decimal Division.	Sexagesimal Division.	
	°	′	″		°	′	″		°	′	″
105	0·743	44	34	120	0·849	50	56	135	0·955	57	17
106	·750		59	121	·856	51	21	136	·962		43
107	·757	45	25	122	·863		46	137	·969	58	08
108	·764		50	123	·870	52	12	138	·976		34
109	·771	46	15	124	·877		37	139	·983		59
110	·778		41	125	·884	53	03	140	·990	59	25
111	·785	47	06	126	·891		28	141	·997		50
112	·792		32	127	·898		54	142	1·004	60	16
113	·799		57	128	·905	54	19	143	·011		41
114	·806	48	23	129	·912		45	144	·018	61	07
115	·813		48	130	·919	55	10	145	·026		32
116	·820	49	14	131	·927		36	146	·033		57
117	·828		39	132	·934	56	01	147	·040	62	23
118	·835	50	05	133	·941		26	148	·047		48
119	·842		30	134	·948		52	149	·054	63	14

TABLE XV.

To convert Chains into Decimals of a Township Side.

Chains.	Equivalent Decimal of a Township Side.		
	Side = 489c.	Side = 486c.	Side = 483c.
1.....	0·00204	0·00206	0·00207
2.....	·00409	·00412	·00414
3.....	·00613	·00617	·00621
4.....	·00818	·00823	·00828
5.....	·01022	·01029	·01035
6.....	·01227	·01235	·01242
7.....	·01431	·01440	·01449
8.....	·01636	·01646	·01656
9.....	·01840	·01852	·01863
10.....	·02045	·02058	·02070
20.....	·04090	·04115	·04141
30.....	·06135	·06173	·06211
40.....	·08180	·08230	·08282
50.....	·10225	·10288	·10352
60.....	·12270	·12346	·12422
70.....	·14315	·14403	·14493
80.....	·16360	·16461	·16563
90.....	·18405	·18519	·18634
100.....	·20450	·20576	·20704
200.....	·40900	·41152	·41408
300.....	·61350	·61728	·62112
400.....	·81800	·82305	·82816

TABLE XVI.

Corrections in Links to Slope Measurements.

Slope.	1 ch.	2 chs.	3 chs.	4 chs.	5 chs.	6 chs.	7 chs.	8 chs.	9 chs.
° ′									
1 30	0·0	0·1	0·1	0·1	0·2	0·2	0·2	0·3	0·3
2 34	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
3 37	0·2	0·4	0·6	0·8	1·0	1·2	1·4	1·6	1·8
4 26	0·3	0·6	0·9	1·2	1·5	1·8	2·1	2·4	2·7
5 08	0·4	0·8	1·2	1·6	2·0	2·4	2·8	3·2	3·6
44	0·5	1·0	1·5	2·0	2·5	3·0	3·5	4·0	4·5
6 17	0·6	1·2	1·8	2·4	3·0	3·6	4·2	4·8	5·4
47	0·7	1·4	2·1	2·8	3·5	4·2	4·9	5·6	6·3
7 15	0·8	1·6	2·4	3·2	4·0	4·8	5·6	6·4	7·2
42	0·9	1·8	2·7	3·6	4·5	5·4	6·3	7·2	8·1
8 07	1·0	2·0	3·0	4·0	5·0	6·0	7·0	8·0	9·0
30	1·1	2·2	3·3	4·4	5·5	6·6	7·7	8·8	9·9
53	1·2	2·4	3·6	4·8	6·0	7·2	8·4	9·6	10·8
9 15	1·3	2·6	3·9	5·2	6·5	7·8	9·1	10·4	11·7
36	1·4	2·8	4·2	5·6	7·0	8·4	9·8	11·2	12·6
56	1·5	3·0	4·5	6·0	7·5	9·0	10·5	12·0	13·5
10 16	1·6	3·2	4·8	6·4	8·0	9·6	11·2	12·8	14·4
35	1·7	3·4	5·1	6·8	8·5	10·2	11·9	13·6	15·3
53	1·8	3·6	5·4	7·2	9·0	10·8	12·6	14·4	16·2
11 11	1·9	3·8	5·7	7·6	9·5	11·4	13·3	15·2	17·1
29	2·0	4·0	6·0	8·0	10·0	12·0	14·0	16·0	18·0
46	2·1	4·2	6·3	8·4	10·5	12·6	14·7	16·8	18·9
12 02	2·2	4·4	6·6	8·8	11·0	13·2	15·4	17·6	19·8
19	2·3	4·6	6·9	9·2	11·5	13·8	16·1	18·4	20·7
35	2·4	4·8	7·2	9·6	12·0	14·4	16·8	19·2	21·6
50	2·5	5·0	7·5	10·0	12·5	15·0	17·5	20·0	22·5
13 06	2·6	5·2	7·8	10·4	13·0	15·6	18·2	20·8	23·4
21	2·7	5·4	8·1	10·8	13·5	16·2	18·9	21·6	24·3
35	2·8	5·6	8·4	11·2	14·0	16·8	19·6	22·4	25·2
50	2·9	5·8	8·7	11·6	14·5	17·4	20·3	23·2	26·1
14 04	3·0	6·0	9·0	12·0	15·0	18·0	21·0	24·0	27·0
18	3·1	6·2	9·3	12·4	15·5	18·6	21·7	24·8	27·9
32	3·2	6·4	9·6	12·8	16·0	19·2	22·4	25·6	28·8
46	3·3	6·6	9·9	13·2	16·5	19·8	23·1	26·4	29·7
59	3·4	6·8	10·2	13·6	17·0	20·4	23·8	27·2	30·6
15 12	3·5	7·0	10·5	14·0	17·5	21·0	24·5	28·0	31·5
25	3·6	7·2	10·8	14·4	18·0	21·6	25·2	28·8	32·4
38	3·7	7·4	11·1	14·8	18·5	22·2	25·9	29·6	33·3
51	3·8	7·6	11·4	15·2	19·0	22·8	26·6	30·4	34·2
16 03	3·9	7·8	11·7	15·6	19·5	23·4	27·3	31·2	35·1

TABLE XVI.—*Continued.*

Corrections in Links to Slope Measurements.

Slope.	1 ch.	2 chs.	3 chs.	4 chs.	5 chs.	6 chs.	7 chs.	8 chs.	9 chs.
° ′									
16 16	4·0	8·0	12·0	16·0	20·0	24·0	28·0	32·0	36·0
28	4·1	8·2	12·3	16·4	20·5	24·6	28·7	32·8	36·9
40	4·2	8·4	12·6	16·8	21·0	25·2	29·4	33·6	37·8
52	4·3	8·6	12·9	17·2	21·5	25·8	30·1	34·4	38·7
17 04	4·4	8·8	13·2	17·6	22·0	26·4	30·8	35·2	39·6
15	4·5	9·0	13·5	18·0	22·5	27·0	31·5	36·0	40·5
27	4·6	9·2	13·8	18·4	23·0	27·6	32·2	36·8	41·4
38	4·7	9·4	14·1	18·8	23·5	28·2	32·9	37·6	42·3
49	4·8	9·6	14·4	19·2	24·0	28·8	33·6	38·4	43·2
18 01	4·9	9·8	14·7	19·6	24·5	29·4	34·3	39·2	44·1
12	5·0	10·0	15·0	20·0	25·0	30·0	35·0	40·0	45·0
23	5·1	10·2	15·3	20·4	25·5	30·6	35·7	40·8	45·9
34	5·2	10·4	15·6	20·8	26·0	31·2	36·4	41·6	46·8
44	5·3	10·6	15·9	21·2	26·5	31·8	37·1	42·4	47·7
55	5·4	10·8	16·2	21·6	27·0	32·4	37·8	43·2	48·6
19 05	5·5	11·0	16·5	22·0	27·5	33·0	38·5	44·0	49·5
16	5·6	11·2	16·8	22·4	28·0	33·6	39·2	44·8	50·4
26	5·7	11·4	17·1	22·8	28·5	34·2	39·9	45·6	51·3
37	5·8	11·6	17·4	23·2	29·0	34·8	40·6	46·4	52·2
47	5·9	11·8	17·7	23·6	29·5	35·4	41·3	47·2	53·1
57	6·0	12·0	18·0	24·0	30·0	36·0	42·0	48·0	54·0
20 07	6·1	12·2	18·3	24·4	30·5	36·6	42·7	48·8	54·9
17	6·2	12·4	18·6	24·8	31·0	37·2	43·4	49·6	55·8
27	6·3	12·6	18·9	25·2	31·5	37·8	44·1	50·4	56·7
37	6·4	12·8	19·2	25·6	32·0	38·4	44·8	51·2	57·6
46	6·5	13·0	19·5	26·0	32·5	39·0	45·5	52·0	58·5
56	6·6	13·2	19·8	26·4	33·0	39·6	46·2	52·8	59·4
21 06	6·7	13·4	20·1	26·8	33·5	40·2	46·9	53·6	60·3
15	6·8	13·6	20·4	27·2	34·0	40·8	47·6	54·4	61·2
25	6·9	13·8	20·7	27·6	34·5	41·4	48·3	55·2	62·1
34	7·0	14·0	21·0	28·0	35·0	42·0	49·0	56·0	63·0
43	7·1	14·2	21·3	28·4	35·5	42·6	49·7	56·8	63·9
52	7·2	14·4	21·6	28·8	36·0	43·2	50·4	57·6	64·8
22 02	7·3	14·6	21·9	29·2	36·5	43·8	51·1	58·4	65·7
11	7·4	14·8	22·2	29·6	37·0	44·4	51·8	59·2	66·6
20	7·5	15·0	22·5	30·0	37·5	45·0	52·5	60·0	67·5
29	7·6	15·2	22·8	30·4	38·0	45·6	53·2	60·8	68·4
38	7·7	15·4	23·1	30·8	38·5	46·2	53·9	61·6	69·3
47	7·8	15·6	23·4	31·2	39·0	46·8	54·6	62·4	70·2
56	7·9	15·8	23·7	31·6	39·5	47·4	55·3	63·2	71·1

TABLE XVI.—*Continued.*

Corrections in Links to Slope Measurements.

Slope.	1 ch.	2 chs.	3 chs.	4 chs.	5 chs.	6 chs.	7 chs.	8 chs.	9 chs.
° ′									
23 04	8·0	16·0	24·0	32·0	40·0	48·0	56·0	64·0	72·0
13	8·1	16·2	24·3	32·4	40·5	48·6	56·7	64·8	72·9
22	8·2	16·4	24·6	32·8	41·0	49·2	57·4	65·6	73·8
31	8·3	16·6	24·9	33·2	41·5	49·8	58·1	66·4	74·7
39	8·4	16·8	25·2	33·6	42·0	50·4	58·8	67·2	75·6
48	8·5	17·0	25·5	34·0	42·5	51·0	59·5	68·0	76·5
56	8·6	17·2	25·8	34·4	43·0	51·6	60·2	68·8	77·4
24 05	8·7	17·4	26·1	34·8	43·5	52·2	60·9	69·6	78·3
13	8·8	17·6	26·4	35·2	44·0	52·8	61·6	70·4	79·2
21	8·9	17·8	26·7	35·6	44·5	53·4	62·3	71·2	80·1
30	9·0	18·0	27·0	36·0	45·0	54·0	63·0	72·0	81·0
38	9·1	18·2	27·3	36·4	45·5	54·6	63·7	72·8	81·9
46	9·2	18·4	27·6	36·8	46·0	55·2	64·4	73·6	82·8
54	9·3	18·6	27·9	37·2	46·5	55·8	65·1	74·4	83·7
25 03	9·4	18·8	28·2	37·6	47·0	56·4	65·8	75·2	84·6
11	9·5	19·0	28·5	38·0	47·5	57·0	66·5	76·0	85·5
19	9·6	19·2	28·8	38·4	48·0	57·6	67·2	76·8	86·4
27	9·7	19·4	29·1	38·8	48·5	58·2	67·9	77·6	87·3
35	9·8	19·6	29·4	39·2	49·0	58·8	68·6	78·4	88·2
43	9·9	19·8	29·7	39·6	49·5	59·4	69·3	79·2	89·1
51	10·0	20·0	30·0	40·0	50·0	60·0	70·0	80·0	90·0
58	10·1	20·2	30·3	40·4	50·5	60·6	70·7	80·8	90·9
26 06	10·2	20·4	30·6	40·8	51·0	61·2	71·4	81·6	91·8
14	10·3	20·6	30·9	41·2	51·5	61·8	72·1	82·4	92·7
22	10·4	20·8	31·2	41·6	52·0	62·4	72·8	83·2	93·6
29	10·5	21·0	31·5	42·0	52·5	63·0	73·5	84·0	94·5
37	10·6	21·2	31·8	42·4	53·0	63·6	74·2	84·8	95·4
45	10·7	21·4	32·1	42·8	53·5	64·2	74·9	85·6	96·3
52	10·8	21·6	32·4	43·2	54·0	64·8	75·6	86·4	97·2
27 00	10·9	21·8	32·7	43·6	54·5	65·4	76·3	87·2	98·1
08	11·0	22·0	33·0	44·0	55·0	66·0	77·0	88·0	99·0
15	11·1	22·2	33·3	44·4	55·5	66·6	77·7	88·8	99·9
23	11·2	22·4	33·6	44·8	56·0	67·2	78·4	89·6	100·8
30	11·3	22·6	33·9	45·2	56·5	67·8	79·1	90·4	101·7
38	11·4	22·8	34·2	45·6	57·0	68·4	79·8	91·2	102·6
45	11·5	23·0	34·5	46·0	57·5	69·0	80·5	92·0	103·5
52	11·6	23·2	34·8	46·4	58·0	69·6	81·2	92·8	104·4
28 00	11·7	23·4	35·1	46·8	58·5	70·2	81·9	93·6	105·3
07	11·8	23·6	35·4	47·2	59·0	70·8	82·6	94·4	106·2
14	11·9	23·8	35·7	47·6	59·5	71·4	83·3	95·2	107·1

TABLE XVI.—*Continued.*

Corrections in Links to Slope Measurements.

Slope.	1 ch.	2 chs.	3 chs.	4 chs.	5 chs.	6 chs.	7 chs.	8 chs.	9 chs.
° ′									
28 21	12·0	24·0	36·0	48·0	60·0	72·0	84·0	96·0	108·0
29	12·1	24·2	36·3	48·4	60·5	72·6	84·7	96·8	108·9
36	12·2	24·4	36·6	48·8	61·0	73·2	85·4	97·6	109·8
43	12·3	24·6	36·9	49·2	61·5	73·8	86·1	98·4	110·7
50	12·4	24·8	37·2	49·6	62·0	74·4	86·8	99·2	111·6
57	12·5	25·0	37·5	50·0	62·5	75·0	87·5	100·0	112·5
29 04	12·6	25·2	37·8	50·4	63·0	75·6	88·2	100·8	113·4
11	12·7	25·4	38·1	50·8	63·5	76·2	88·9	101·6	114·3
18	12·8	25·6	38·4	51·2	64·0	76·8	89·6	102·4	115·2
25	12·9	25·8	38·7	51·6	64·5	77·4	90·3	103·2	116·1
32	13·0	26·0	39·0	52·0	65·0	78·0	91·0	104·0	117·0
39	13·1	26·2	39·3	52·4	65·5	78·6	91·7	104·8	117·9
46	13·2	26·4	39·6	52·8	66·0	79·2	92·4	105·6	118·8
53	13·3	26·6	39·9	53·2	66·5	79·8	93·1	106·4	119·7
30 00	13·4	26·8	40·2	53·6	67·0	80·4	93·8	107·2	120·6
07	13·5	27·0	40·5	54·0	67·5	81·0	94·5	108·0	121·5
14	13·6	27·2	40·8	54·4	68·0	81·6	95·2	108·8	122·4
21	13·7	27·4	41·1	54·8	68·5	82·2	95·9	109·6	123·3
27	13·8	27·6	41·4	55·2	69·0	82·8	96·6	110·4	124·2
34	13·9	27·8	41·7	55·6	69·5	83·4	97·3	111·2	125·1
41	14·0	28·0	42·0	56·0	70·0	84·0	98·0	112·0	126·0
48	14·1	28·2	42·3	56·4	70·5	84·6	98·7	112·8	126·9
54	14·2	28·4	42·6	56·8	71·0	85·2	99·4	113·6	127·8
31 01	14·3	28·6	42·9	57·2	71·5	85·8	100·1	114·4	128·7
08	14·4	28·8	43·2	57·6	72·0	86·4	100·8	115·2	129·6
14	14·5	29·0	43·5	58·0	72·5	87·0	101·5	116·0	130·5
21	14·6	29·2	43·8	58·4	73·0	87·6	102·2	116·8	131·4
28	14·7	29·4	44·1	58·8	73·5	88·2	102·9	117·6	132·3
34	14·8	29·6	44·4	59·2	74·0	88·8	103·6	118·4	133·2
41	14·9	29·8	44·7	59·6	74·5	89·4	104·3	119·2	134·1
47	15·0	30·0	45·0	60·0	75·0	90·0	105·0	120·0	135·0
54	15·1	30·2	45·3	60·4	75·5	90·6	105·7	120·8	135·9
32 00	15·2	30·4	45·6	60·8	76·0	91·2	106·4	121·6	136·8
07	15·3	30·6	45·9	61·2	76·5	91·8	107·1	122·4	137·7
13	15·4	30·8	46·2	61·6	77·0	92·4	107·8	123·2	138·6
20	15·5	31·0	46·5	62·0	77·5	93·0	108·5	124·0	139·5
26	15·6	31·2	46·8	62·4	78·0	93·6	109·2	124·8	140·4
33	15·7	31·4	47·1	62·8	78·5	94·2	109·9	125·6	141·3
39	15·8	31·6	47·4	63·2	79·0	94·8	110·6	126·4	142·2
45	15·9	31·8	47·7	63·6	79·5	95·4	111·3	127·2	143·1

TABLE XVI.—*Concluded.*

Corrections in Links to Slope Measurements.

Slope.	1 ch.	2 chs.	3 chs.	4 chs.	5 chs.	6 chs.	7 chs.	8 chs.	9 chs.
° ′									
32 52	16·0	32·0	48·0	64·0	80·0	96·0	112·0	128·0	144·0
58	16·1	32·2	48·3	64·4	80·5	96·6	112·7	128·8	144·9
33 04	16·2	32·4	48·6	64·8	81·0	97·2	113·4	129·6	145·8
11	16·3	32·6	48·9	65·2	81·5	97·8	114·1	130·4	146·7
17	16·4	32·8	49·2	65·6	82·0	98·4	114·8	131·2	147·6
23	16·5	33·0	49·5	66·0	82·5	99·0	115·5	132·0	148·5
29	16·6	33·2	49·8	66·4	83·0	99·6	116·2	132·8	149·4
36	16·7	33·4	50·1	66·8	83·5	100·2	116·9	133·6	150·3
42	16·8	33·6	50·4	67·2	84·0	100·8	117·6	134·4	151·2
48	16·9	33·8	50·7	67·6	84·5	101·4	118·3	135·2	152·1
54	17·0	34·0	51·0	68·0	85·0	102·0	119·0	136·0	153·0
34 00	17·1	34·2	51·3	68·4	85·5	102·6	119·7	136·8	153·9
06	17·2	34·4	51·6	68·8	86·0	103·2	120·4	137·6	154·8
12	17·3	34·6	51·9	69·2	86·5	103·8	121·1	138·4	155·7
19	17·4	34·8	52·2	69·6	87·0	104·4	121·8	139·2	156·6
25	17·5	35·0	52·5	70·0	87·5	105·0	122·5	140·0	157·5
31	17·6	35·2	52·8	70·4	88·0	105·6	123·2	140·8	158·4
37	17·7	35·4	53·1	70·8	88·5	106·2	123·9	141·6	159·3
43	17·8	35·6	53·4	71·2	89·0	106·8	124·6	142·4	160·2
49	17·9	35·8	53·7	71·6	89·5	107·4	125·3	143·2	161·1
55	18·0	36·0	54·0	72·0	90·0	108·0	126·0	144·0	162·0
35 01	18·1	36·2	54·3	72·4	90·5	108·6	126·7	144·8	162·9
07	18·2	36·4	54·6	72·8	91·0	109·2	127·4	145·6	163·8
13	18·3	36·6	54·9	73·2	91·5	109·8	128·1	146·4	164·7
19	18·4	36·8	55·2	73·6	92·0	110·4	128·8	147·2	165·6
25	18·5	37·0	55·5	74·0	92·5	111·0	129·5	148·0	166·5
31	18·6	37·2	55·8	74·4	93·0	111·6	130·2	148·8	167·4
37	18·7	37·4	56·1	74·8	93·5	112·2	130·9	149·6	168·3
42	18·8	37·6	56·4	75·2	94·0	112·8	131·6	150·4	169·2
48	18·9	37·8	56·7	75·6	94·5	113·4	132·3	151·2	170·1
54	19·0	38·0	57·0	76·0	95·0	114·0	133·0	152·0	171·0
36 00	19·1	38·2	57·3	76·4	95·5	114·6	133·7	152·8	171·9
06	19·2	38·4	57·6	76·8	96·0	115·2	134·4	153·6	172·8
12	19·3	38·6	57·9	77·2	96·5	115·8	135·1	154·4	173·7
18	19·4	38·8	58·2	77·6	97·0	116·4	135·8	155·2	174·6
23	19·5	39·0	58·5	78·0	97·5	117·0	136·5	156·0	175·5
29	19·6	39·2	58·8	78·4	98·0	117·6	137·2	156·8	176·4
35	19·7	39·4	59·1	78·8	98·5	118·2	137·9	157·6	177·3
41	19·8	39·6	59·4	79·2	99·0	118·8	138·6	158·4	178·2
46	19·9	39·8	59·7	79·6	99·5	119·4	139·3	159·2	179·1
52	20·0	40·0	60·0	80·0	100·0	120·0	140·0	160·0	180·0

TABLE XVII.

Table for Laying Out Roads One Chain Wide.

Difference of Bearing.		Links.	Difference of Bearing.		Links.	Difference of Bearing.		Links.
° ′	° ′		° ′	° ′		° ′	° ′	
360 00	0 00	100	275 35	84 25	135	252 04	107 56	170
343 52	16 08	101	274 40	85 20	136	251 35	108 25	171
337 16	22 44	102	273 46	86 14	137	251 06	108 54	172
332 16	27 44	103	272 53	87 07	138	250 38	109 22	173
328 07	31 53	104	272 01	87 59	139	250 10	109 50	174
324 30	35 30	105	271 10	88 50	140	249 42	110 18	175
321 16	38 44	106	270 21	89 39	141	249 15	110 45	176
318 19	41 41	107	269 32	90 28	142	248 48	111 12	177
315 37	44 23	108	268 44	91 16	143	248 22	111 38	178
313 06	46 54	109	267 58	92 02	144	247 56	112 04	179
310 46	49 14	110	267 12	92 48	145	247 30	112 30	180
308 33	51 27	111	266 28	93 32	146	247 05	112 55	181
306 28	53 32	112	265 44	94 16	147	246 40	113 20	182
304 30	55 30	113	265 01	94 59	148	246 15	113 45	183
302 37	57 23	114	264 19	95 41	149	245 50	114 10	184
300 49	59 11	115	263 37	96 23	150	245 26	114 34	185
299 06	60 54	116	262 57	97 03	151	245 03	114 57	186
297 27	62 33	117	262 17	97 43	152	244 39	115 21	187
295 52	64 08	118	261 38	98 22	153	244 16	115 44	188
294 21	65 39	119	260 59	99 01	154	243 53	116 07	189
292 53	67 07	120	260 21	99 39	155	243 31	116 29	190
291 28	68 32	121	259 44	100 16	156	243 09	116 51	191
290 06	69 54	122	259 08	100 52	157	242 47	117 13	192
288 47	71 13	123	258 32	101 28	158	242 25	117 35	193
287 30	72 30	124	257 57	102 03	159	242 03	117 57	194
286 16	73 44	125	257 22	102 38	160	241 42	118 18	195
285 03	74 57	126	256 48	103 12	161	241 21	118 39	196
283 53	76 07	127	256 14	103 46	162	241 01	118 59	197
282 45	77 15	128	255 41	104 19	163	240 40	119 20	198
281 39	78 21	129	255 09	104 51	164	240 20	119 40	199
280 34	79 26	130	254 37	105 23	165	240 00	120 00	200
279 31	80 29	131	254 05	105 55	166			
278 30	81 30	132	253 34	106 26	167			
277 30	82 30	133	253 04	106 56	168			
276 32	83 28	134	252 34	107 26	169			

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